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Evaluation of the Refuse Management System at the Jersey City Operation Breakthrough Site

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This study evaluates the solid waste management system at the Jersey City Operation Breakthrough site and assesses the economic and technical practicality of the system application for future residential complexes. The installation was the first pneumatic trash collection system (PTC) used to collect residential refuse in the U.S. This report describes labor costs, rodents and vermin, odor, litter, and collection noise. The report also compares cost and operation of the PTC system with those aspects of conventional collection systems.

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by

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Contract No. 68-03-0094

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to health and welfare of the American people. Noxious air, foul water, and soiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components requires a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of waste-water and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes the operation and economics of the pneumatic trash collection system at the Department of Housing and Urban Development's Operation Breakthrough site at Jersey City, New Jersey. The information in this document should be extremely useful to decision makers in planning future high population density residential complexes.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

This study evaluates the solid waste management system at the Jersey City Operation Breakthrough site and assesses the economic and technical practicality of the system application for future residential communities. The installation was the first pneumatic trash collection system (PTC) used to collect residential refuse in the U.S. The annual cost for the PTC system, $120,021 to collect 248 tons of refuse, ranged from 160 to 460 percent more expensive than conventional systems, but would be cost-effective if operated at design capacity. Over an eighteen month monitoring period the PTC system was operable only 54 percent of the time, had a 50 percent probability of failure within 16 hours or 15 cycles of operation. Following failures, probabilities of being again operable were 50 and 83 percent within 3.4 and 24 calendar hours, respectively. The main transport line, programmer, discharge valves, control panel, vertical trash chutes, and compactor caused 88 percent of all system malfunctions, 94 percent of total downtime, and 91 percent of all repair man-hours. Design recommendations are presented that could increase system availability to about 86 percent. Additionally, recommendations are made for use in future residential complexes. In comparison with conventional systems, the PTC system has as benefits reduced labor costs, the non-appearance of rodents and vermin, and the elimination of odor, litter, and collection noise. Additionally, the refuse collection system was completely automatic, except for final disposal of site refuse.

The report is submitted in partial fulfillment of Contract Number 68-03-0094 by Hittman Associates, Inc., was prepared for the Environmental Protection Agency, was sponsored by the Office of Policy Development and Research, Division of Energy, Building Technology, and Standards, Department of Housing and Urban Development, and the work was performed from December 1971 through May 1977.

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ABBREVIATIONS

SFA	single-family attached dwelling units
SFD	single-family detached dwelling units
MFLR	multifamily low-rise dwelling units
MFMR	multifamily medium-rise dwelling units
MFHR	multifamily high-rise dwelling units
PTC	pneumatic trash collection
CEB	Central Equipment Building
OSHA	Occupational Safety and Health Administration

CONVERSION UNITS

1 foot = 0.3048 meter

1 cubic yard = 0.7646 cubic meter

1 cubic foot = 0.0283 cubic meter

1 foot/sec = 0.3048 meter/sec

1 pound = 0.4536 kilogram

1 ton = 907.2 kilogram

1 pound/cubic foot = 16.02 kilogram/cubic meter

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SECTION I

INTRODUCTION

BACKGROUND

The Department of Housing and Urban Development Operation Breakthrough Program is involved in the demonstration of innovative building and design concepts for residential communities. As part of this program, a pneumatic trash collection (PTC) system was installed at the Jersey City Operation Breakthrough site in conjunction with a total energy system. The installation is the first time a PTC system has been installed in a residential complex in the United States even though similar systems have been installed in hospitals and other non-residential complexes. The PTC system was installed to evaluate the performance and effectiveness and to determine the feasibility for use in future residential projects.

The average city dweller discards from one to four pounds of refuse per day which means from three to twelve pounds per day must be disposed from a dwelling unit. For an apartment complex of 486 dwelling units, the total daily refuse load is from 1458 to 5832 pounds. In most residential apartment complexes, the refuse is disposed by each family or a building janitor in a central collection point where it is stored until picked up and hauled to a landfill or incinerator. This method has the disadvantages of noise, odors, poor sanitation, and possibly being labor intensive and costly.

In some European countries where labor and material costs are very high, automatic waste-collection systems have been found more economical than conventional systems in high-rise residential complexes.

Because a PTC system had never been applied to collect residential refuse in the United States, the evaluation assumes the important task of determining the practicality of the system and to guide the development of such systems for use in larger scale projects in the future.

This report presents the results of the evaluation of the PTC system installed and operated in the Jersey City Operation Breakthrough site. In addition a separate report documents the results of a survey at the site to determine resident and management acceptance of the refuse system (Ref. 1). Those results are summarized in this report. Also, an executive report is prepared to summarize all work efforts and results of the PTC system evaluation, the evaluation of refuse management systems at Operation Breakthrough sites, and the refuse system user acceptance surveys at eight of the nine Operation Breakthrough sites.

BRIEF OPERATIONAL DESCRIPTION

When a resident at the Jersey City site has a full wastebasket, it is carried to the disposal chute on the resident's floor. The chute is at normal air pressure, and there is no suction or blowing of trash. The refuse falls until it lands on a horizontal plate at the bottom of the chute. This plate is actually a valve separating the chute from a horizontal steel pipe 20 inches in diameter running to the central collection point. The horizontal pipe operates at a pressure of between 8 and 9 pounds per square inch pressure which is created by an air pump called an "exhauster." The chute valves in the pipe network are opened one at a time, automatically on a fixed schedule, and the accumulated trash falls into the horizontal pipe and is swept along to the central collection point in the partially evacuated horizontal pipe by air which is moving at about 60 miles per hour. The solid waste is collected in the central collection hopper. There it is compacted automatically and stored until trucks carry the sealed containers to a Jersey City landfill. The outside air is pulled into the system of horizontal pipes through an intake valve by the exhauster. The spent air from the exhauster is purified in high-efficiency filters and released to the environment through an exhaust plenum which acts as a silencer. Although the stream of air in the pipes travels at a mile a minute, it is not unreasonable to be concerned about the ability of the system to transport bottles and other dense solids to the collection point. Experience indicates that any dense solids that separate from lighter materials being carried along by the air are ultimately shoved into the hopper by batches of lighter material that coax them along even if the pipes slant upwards as much as thirty degrees.

The projected operating costs for the PTC system are expected to be lower than those for conventional collection systems. Furthermore, the PTC system is expected to be more convenient, quieter, and more sanitary than conventional collection systems.

STUDY OBJECTIVES

The study is a detailed evaluation of the performance of the PTC system installed and operated at the Operation Breakthrough site in Jersey City, New Jersey. System performance is evaluated with respect to achievement of design specifications. Overall evaluations are made of the system performance with respect to technical, economic, resident acceptance, and environmental factors. Specific objectives are discussed in the following paragraphs.

Technical Evaluation Objectives

The technical objectives are to determine overall system performance and to estimate the service life for the system. To accomplish these objectives the following specific technical areas were investigated.

Reliability and Maintainability --
The system reliability and maintainability is evaluated using operational data collected during an 18 month monitoring period. These data were analyzed to determine:

- The availability of the system and the probability that the system will be in an operable mode at any time;
- The probability that the system can continue to collect refuse automatically after the completion of a specified number of cycles;
- The probable repair time required to correct malfunctions;

- The effects of system malfunctions on the collection service;
- The effects and probability of a major system breakdown; and
- The reliability and maintainability characteristics of the system and recommendations for consideration in the design of future PTC system applications.

Performance --
The system performance is evaluated to determine the effectiveness of the PTC system in terms of:

- The ability to meet design criteria for the refuse loads and economics for the site;
- The ability to transport various shapes and densities of refuse, including oversize, overweight, and other bulky items;
- The capacity of the system for the design loads, actual loads, and operating schedule, including determination of the optimum operating schedule;
- The ability to safely handle dangerous materials;
- The adaptability of the system to recycle specific solid waste classes;
- The ability to recover valuable items mistakenly placed in the system; and
- The adequacy of safety equipment including provisions to prevent injury to residents, provide fire prevention, and provide safety to operating personnel.

Expected Service Life --
The service life of the PTC system is determined by evaluating the operational degradation and wear with respect to service time over an 18 month period.

Economic Evaluation Objectives

The economic evaluation objectives are to determine the capital, operational, and maintenance costs and to compare these costs to design estimates. These costs were obtained from the government and during the 18 month monitoring period. All costs are categorized and evaluated to determine:

- Capital costs including initial procure ment and installation, major components, control instrumentation, and contingency items costs;
- Operational and maintenance costs, including labor, hauling and landfill, energy, material, and other costs; and
- The annualized costs of owning and operating the system on the basis of costs per dwelling unit, capita, and ton of refuse disposed.

In addition, the PTC system annualized costs are compared to the estimated costs of a conventional system which might have been installed at the site.

Resident Acceptance Evaluation Objectives

The level of resident acceptance is evaluated in a separate study (Ref. 1) and summarized. That study summarized and determined:

- The type of resident at the site;
- The resident awareness of requirements of the collection system; and
- The resident and management acceptance of the PTC system.

Environmental Evaluation Objectives

The objectives of the environmental effects evaluation are to determine:

- Sanitation effects such as litter, cleanliness, odor, and presence of rodents and vermin;

- Air quality of the system, internal air the exhaust air, including airborne particulates and viable particles;

- Noise levels produced by the refuse collection activities compared to background noise levels and acceptability to residential use of the system;

- Aesthetic qualities attributed to the system; and

- Advantages of a reduced number of service vehicles visits to the site to pick up and dispose refuse.

SITE DESCRIPTION

The Jersey City Operation Breakthrough site, which is located in a high density area, is composed of seven buildings. The site plan is presented in Figure 1. The four residential buildings (by builder designators) are Shelley A, Selley B, Descon Concordia, and Camci. The other buildings are the Commercial Building, School, and Central Equipment Building (CEB). All prime utility equipment including PTC system equipment and a total energy plant are located in the CEB. The Commercial Building was completed during the evaluation period. The school building was completed after the evaluation period and therefore is not included. The solid waste management system serviced the four residential buildings during most of the 18 month monitoring period. Demographic and related data are reported in Table 1.

REFUSE SYSTEM DESCRIPTION

The pneumatic trash collection (PTC) system automatically collects all the solid waste generated at the site, with the exception of bulky waste, and compacts this refuse into sealed containers. A detailed description of these components is presented in Table 2. The entire operation of the system is regulated by a central control panel. The fully ladened refuse containers are hauled to a sanitary landfill by a pull-on container truck.

The following steps, as illustrated in Figure 2, occur whenever refuse is collected by the PTC system.

- Refuse is disposed of by a tenant at a chute charging station. A station is usually located near the elevator.

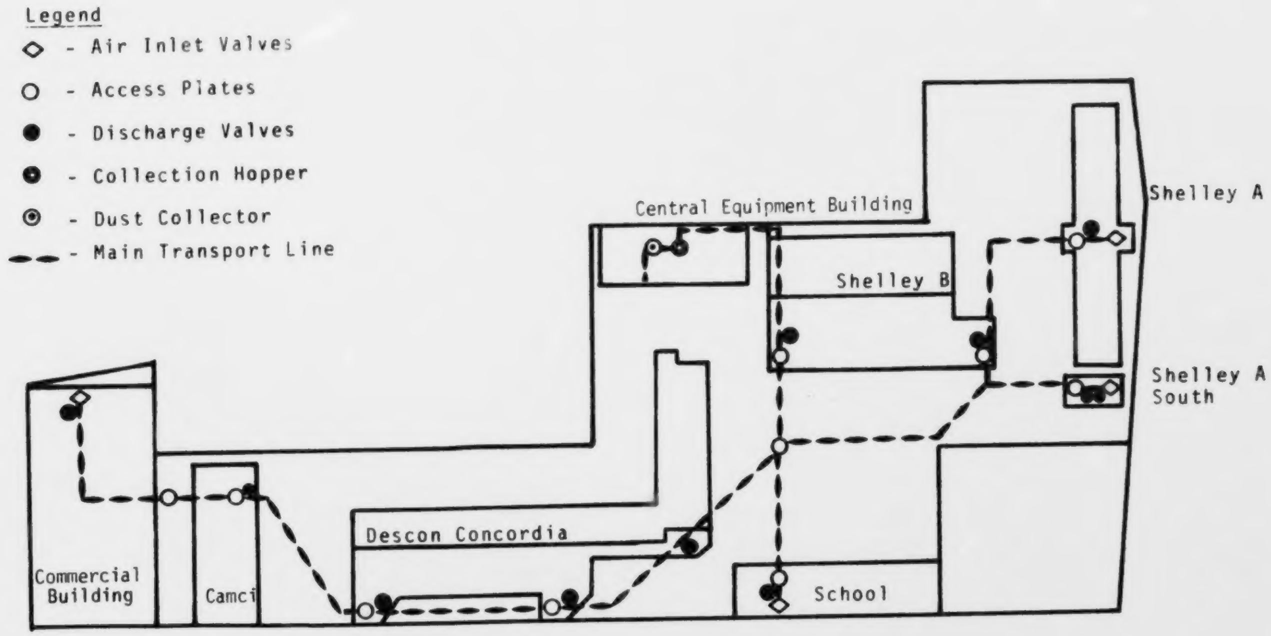
Legend
◇ - Air Inlet Valves
○ - Access Plates
● - Discharge Valves
● - Collection Hopper
⊙ - Dust Collector
- Main Transport Line
Central Equipment Building
Shelley A
Shelley B
Shelley A South
Descon Concordia
School
Commercial Building
Camci

FIGURE 1. Jersey City Operation Breakthrough site arrangement showing location of PTC equipment.

Table 1. DEMOGRAPHIC AND SOLID WASTE SYSTEM DESCRIPTIVE DATA FOR THE JERSEY CITY OPERATION BREAKTHROUGH SITE

Site area is 6.35 acres.

Building	Number of Units	Number of Residents[1]	Number of Charging Stations	Number of Discharge Valves	Units Per Chute	Units Per Charging Station	Residents Per Charging Station
Shelley A	152 MFHR	456	18	1	152	8.4	25
Shelley A South[2]	-0-	-0-	2	2	-0-	-0-	-0-
Shelley B[3]	40 MFMR	150	8	2	20	5.0	19
Descon Concordia	12 MFLR 24 MFMR 105 MFHR	326	12	3	47	11.8	27
Camci[5]	153 MFHR	323	16	1	153	9.6	20
TOTALS	486 units	1255	56	9			

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[1] *It is assumed that there are 1.5 residents per bedroom. Site management states that total number of residents varies from 1200 to 1300 people.*

[2] *This is a small shed with one charging station for yard waste and another charging station for tenant use.*

[3] *One charging station is used by site personnel in addition to residents.*

[4] *Two chutes are located on the deck level, and are used by the tenants on the lowest floor at Descon Concordia and for recreational waste.*

[5] *The first floor charging station is used by office tenants.*

Table 2. DETAILED DESCRIPTION OF PTC SYSTEM COMPONENTS

Component	Manufacturer and Model Number	Function	Remarks
AIR INLET VALVE	Envirogenics design	Allows air to enter the upstream ends of the main transport line.	The valve is a butterfly valve that is pneumatically operated.
DISCHARGE VALVE	Envirogenics design	Isolates trash from main transport line so that each station may be individually cycled.	Horizontal plate valve that is pneumatically operated.
COLLECTION HOPPER	Envirogenics design	Collects solid waste and separates the air stream from it.	A hopper screen is installed at the exit line from the hopper to separate the air from the refuse. A hopper gate over the compactor unit allows a vacuum to be used in the system. After the main exhauster is off, it opens to let refuse fall to the compactor unit.
DUST COLLECTOR	Mikropul Mikro-Pulsaire Dust Collector Model	Removes particulate matter and viable particles from the air stream.	The dust collector is a baghouse filter. At the base there is a rotary valve to dispose dust particles into a waste line.
MAIN EXHAUSTER	Hoffman Centrifugal Exhausters No. 77102	Provides vacuum to collect solid waste.	Each exhauster is coupled to a 150 HP frame 3,600 RPM induction motor. Provides 11,300 cfm of air at a vacuum of 3.5 inches of mercury which is equivalent to a 60 mph wind.
PLENUM	Envirogenics design	Muffles the noise produced by this system.	It is a chamber with the following dimensions: 3 ft wide by 9.5 ft long by 18.5 ft high.
COMPACTOR	Dempster Brothers, Inc. Model Number SP 38-42	Compacts the collected refuse into a refuse container.	The hydraulically powered unit compacts the site refuse into 25-cu yd containers.
VENT FAN	Model Number 5K 145AL64 Industrial Exhauster by Buffalo Forge Co.	Provides a negative pressure in the line and in the vertical gravity chutes to prevent odors from escaping into the residential buildings.	Chute bypass valves have been installed at those discharge valves located in the MFMR and MFHR buildings to allow the vent fan to remove odors. These valves are butterfly valves which are pneumatically operated.
MAIN TRANSPORT LINE	Envirogenics design	Moves refuse from the vertical gravity chutes to the equipment in the CEB.	This is a 20-inch nominal diameter low carbon steel line with 1/2-inch wall thickness.

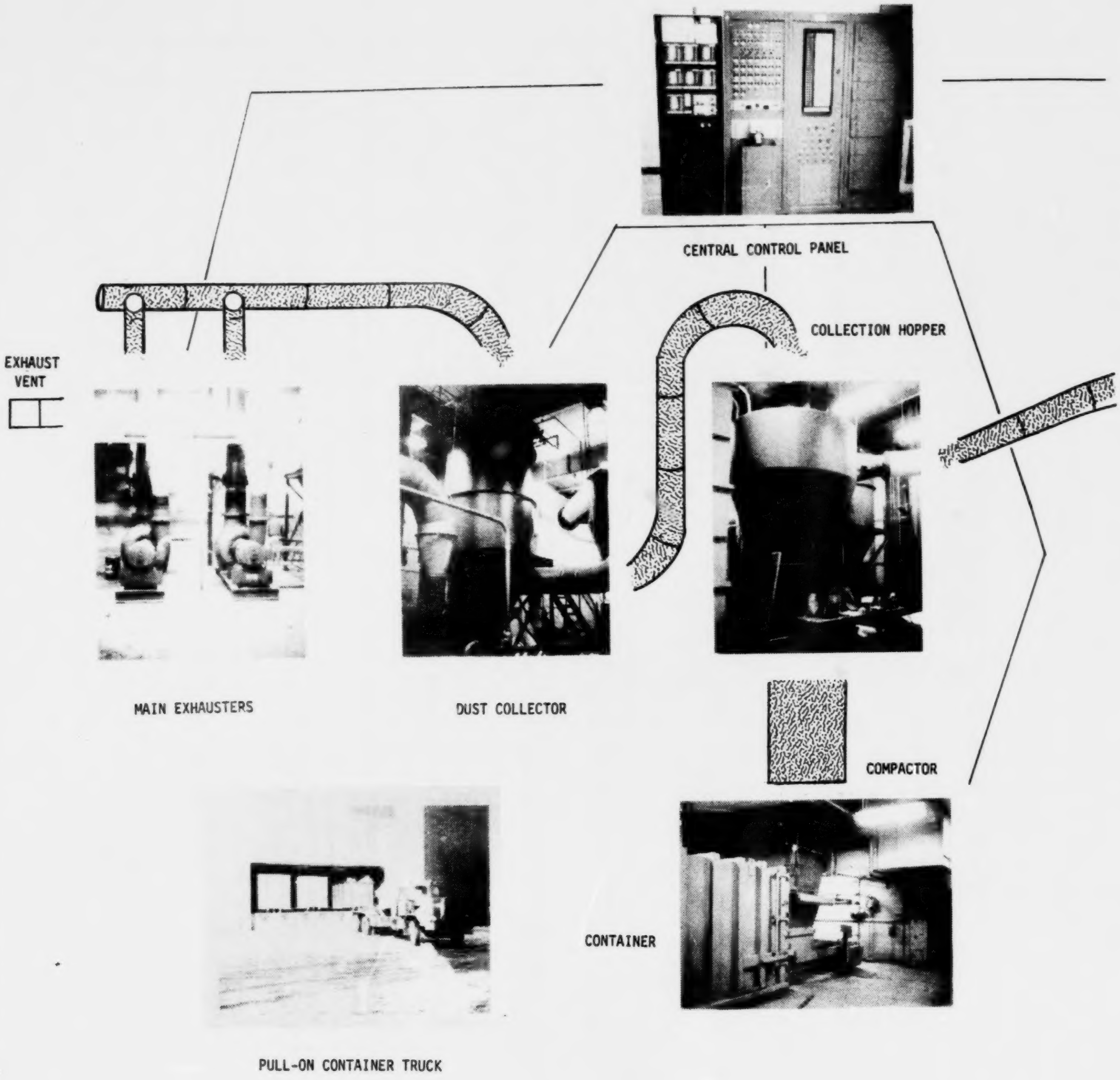
CENTRAL CONTROL PANEL
COLLECTION HOPPER
EXHAUST VENT
MAIN EXHAUSTERS
DUST COLLECTOR
COMPACTOR
CONTAINER
PULL-ON CONTAINER TRUCK

FIGURE 2. A perspective view of the main components in the PTC system.

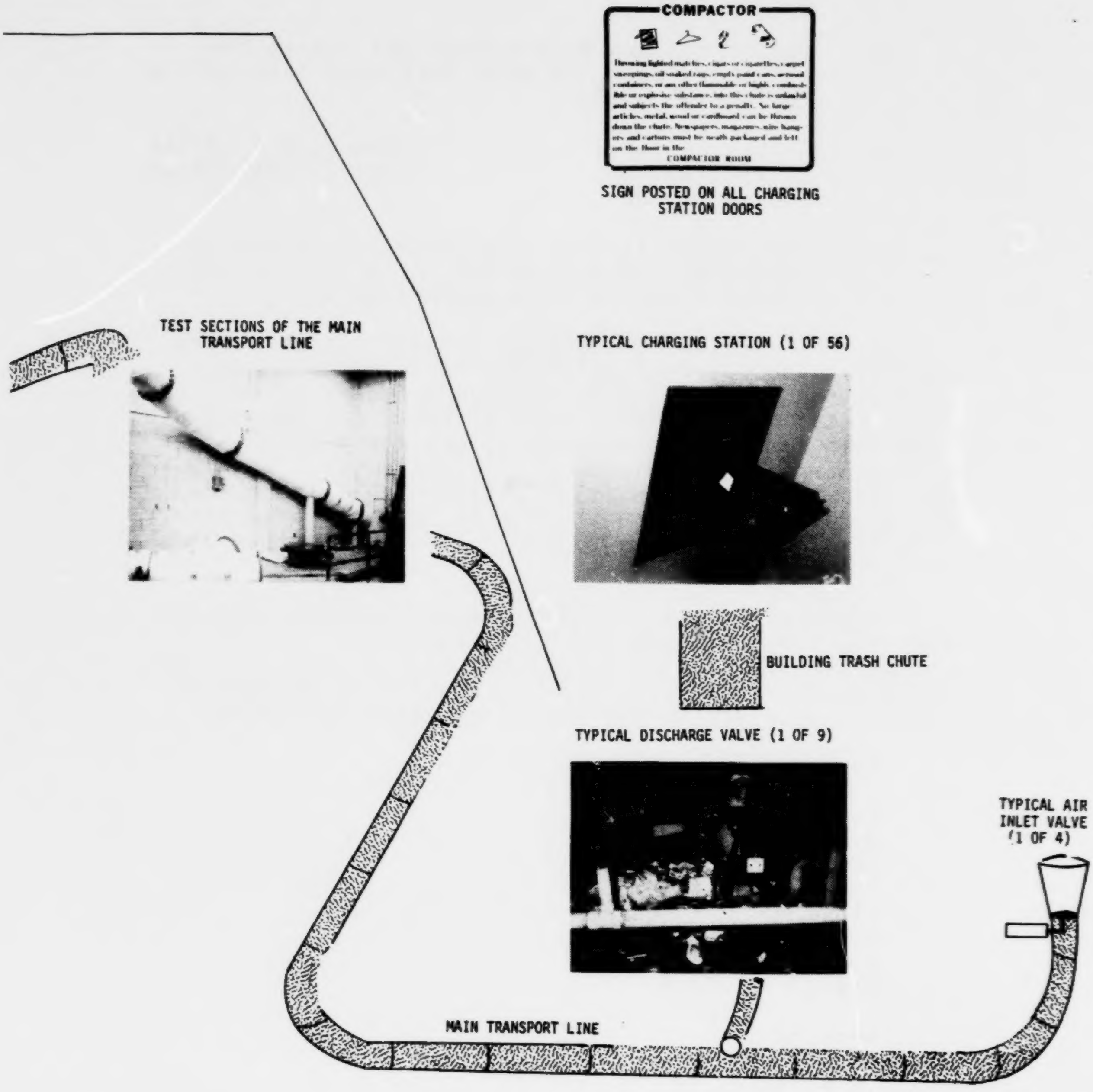
COMPACTOR
Throwing lighted matches, cigars or cigarettes, carpet sweepings, oil soaked rags, empty paint cans, aerosol containers, or any other flammable or highly combustible or explosive substance, into this chute is unlawful and subjects the offender to a penalty. No large articles, metal, wood or cardboard can be thrown down the chute. Newspapers, magazines, wire hangers and cartons must be neatly packaged and left on the floor in the
COMPACTOR ROOM
SIGN POSTED ON ALL CHARGING STATION DOORS
TEST SECTIONS OF THE MAIN TRANSPORT LINE
TYPICAL CHARGING STATION (1 OF 56)
BUILDING TRASH CHUTE
TYPICAL DISCHARGE VALVE (1 OF 9)
TYPICAL AIR INLET VALVE (1 OF 4)
MAIN TRANSPORT LINE

FIGURE 2. (continued)

- The refuse falls down a vertical chute and rests at a storage section above the discharge valve.
- One of the two main exhausters convey the refuse through the main transport line to the collection hopper.
- A dust collector, installed downstream of the collection hopper, removes particulate matter and viable particles.
- The refuse is then compacted into a sealed container and hauled away by a pull-on container truck to a sanitary landfill.

The PTC system is designed to be a quieter, more sanitary, and odorless service as well as to be convenient for users. The main components are production line units. This reduces capital costs and demonstrates that this system can be designed and constructed with readily available equipment. The system is ultimately designed to reduce operating costs, manual labor, and energy requirements and thereby to provide for a more effective and efficient refuse collection service than conventional systems.

The design load for this refuse collection system was 1300 tons per year which is equivalent to 7125 pounds per day or 4.75 pounds per capita per day. The solid wastes to be conveyed are classified as typical residential waste of the following characteristics:

Composition by Weight

Paper	33.0%
Wood	0.3
Plastic	6.8
Rags	6.4
Glass	16.1
Metal	10.7
Stone	0.3
Misc.	26.4

Density

5.6 lbs/cu ft
89.7 kg/cu m

SECTION II

CONCLUSIONS

This report presents the results of the technical and economic data gathered during an 18 month monitoring period of the solid waste management system at the Jersey City Operation Breakthrough site. The overall objective of this study is to assess the economics, effectiveness, and feasibility of using PTC systems in residential developments. General conclusions for the PTC system were:

- The system was unreliable which caused excessive downtimes and frequent service interruptions;
- The system was over specified and designed for the actual refuse loading capacities at the site;
- The economics of the system, particularly capital costs, were excessive;
- The residents and site management readily accepted the system for its convenience and the removal of many signs of refuse collection activities; and
- The environmental effects including litter, cleanliness, odor, and the presence of vermin and rodents were effectively controlled and site aesthetics were maintained.

Specific conclusions, based on the evaluation of this study, are reported in the following areas:

- Technical,
- Economic,
- Resident Acceptance, and
- Environmental.

TECHNICAL CONCLUSIONS

Reliability and Maintainability

Using the operational data collected during an 18 month monitoring period, the availability of the PTC system was calculated to be 54 percent. Design specifications stated that the system should be in an operable mode around 97 percent of the time. Accordingly, the system did not meet design expectations.

The probability that the system will successfully operate (without failure) for a given number of cycles decreases drastically as the number of cycles increases. There is a 50 percent probability of failure for 16 hours (15 cycles) of operation and a 90 percent probability of failures for 40 hours (37 cycles) of operation. The system exhibited 16 hours (15 cycles) mean time between failures. This represents a very, very low reliability.

Analysis of the data showed that total calendar downtime increased with the extent of the system malfunction. Fifty percent of the malfunctions were repaired within three hours of total downtime while 10 percent of the malfunctions required 36 hours. However, 60 percent of the malfunctions were repaired within one-half hour after repair work was actively begun. Considerable amounts of downtime were attributable to the site personnels slow response in reacting to system problems.

The design specifications called for all system malfunctions to be repaired within 24 hours. The operational data indicated that 16 percent of the malfunctions required more than 24 hours for repairs, which did not comply with the design criteria.

The probability of a major system breakdown is directly related to the probability of a failure with six critical components. These components were the main transport line, the programmer, the discharge valves, the control panel, the vertical trash chutes, and the compactor. They contributed to 88 percent of all system malfunctions, 94 percent of all downtime, 89 percent of the total repair time, and 91 percent of the total man-hours needed to effect repairs. It was found that design improvements for these components could reduce the total number of system malfunctions by 51 percent, total downtime by 62 percent, total repair time by 46 percent, and total man-hours for repair by 51 percent. Futhermore, the system availability would be increased by 32 percent, or be about 86 percent.

The effects of system malfunctions were more pronounced as the amount of time that the system did not operate increased. Minor problems with sanitation, litter, and odor were experienced with short downtime periods. Whenever the downtime exceeded 24 hours, major problems ensued. As a result of the PTC system being inoperable for periods longer than 24 hours, an alternative refuse collection service was required. During these periods, the site personnel manually collected refuse which was a highly labor-intensive activity.

The prolonged downtime and the alternative collection service combined to cause a variety of problems with litter, odor, and vermin. At times, these sanitation conditions were so repulsive that the residents complained to the site management.

Performance

Evaluation of the operational data indicated that the PTC did meet the design capacity criteria for the refuse loads; however, the loads at the site were only about one-sixth of design load criteria. The observed load was about 248 tons per year, while the design load criteria was from 1300 to 1600 tons per year.

The design specifications stated that the system must be able to collect refuse with densities ranging to 50 pounds per cubic foot. Under normal operating conditions, the system complied with these qualifications. The transport velocities for refuse of 10 and 50 pounds per cubic foot were observed to be about 50 and 27 feet per second, respectively. Additionally, it was noticed that many overweight, oversize, and other bulky items were collected without any problems. At times, small refuse samples on the order of 100 pounds per cubic foot could be safely collected. The refuse load, however, from the residences averaged about two pounds per cubic foot.

The operating schedule of 18 cycles per day more than adequately handled the actual loads of the PTC system. One reason for this was that, as mentioned previously, the actual loads were only one-sixth of the design loads. It was determined that for the actual loads, the optimum operating schedule would be between seven and nine cycles per day. The times for the cycling of the system may vary due to daily, seasonal, and other load factors.

The PTC system did have the ability to safely handle some types of dangerous materials. Residents were informed not to dispose of certain items which would be hazardous to the system. Overall, these restrictions were followed. In spite of these precautions, several dangerous materials such as aerosal cans were placed into the system. These cans were safely collected and created no problems.

The investigations into the adaptability of the system to recycle specific solid waste classes showed that the system could be modified to do so without major design changes and with reasonable success. The modifications would most likely be centered around the collection hopper. The quantities of recycled solid waste annually could be about 148 tons of paper, 18 tons of glass, 20 tons of metal, and 10 tons of plastic. This would amount to about 196 tons, or 79 percent of the annual refuse loading.

Observations from the monitoring program revealed that valuable items mistakenly placed into the system could be recovered, however, the probability of retrieving the item undamaged is small. The chances of recovery and the effort required for recovery depend upon the extent of system operations. By way of illustration, the likelihood of rescuing an item mistakenly placed in the system is good, if a collection cycle has not been initiated. If, however, the cycle has been completed, the possibility of obtaining the item is poor. Therefore, care should be exercised to insure that valuable items are not placed into the system.

The design specifications for the system called for equipment to prevent component and plant failures, service interruptions, fires, and personnel injuries. Many of the PTC system safety features did not satisfy these requirements. To cite two examples, a fire detection and sprinkler system failed to operate in one of the trash chutes when a fire occurred. Also, a high temperature alarm cable for a main exhauster caught on fire. These failures could be attributed to poor inspection techniques. For the most part, the safety equipment for the PTC system did prevent injury and property damage.

The performance of the system deteriorated with low room temperatures. Because components were located in rooms that were not properly heated, and components were built to operate properly at normal room temperatures, component failures occurred. Most of these failures were related to ice formation in the pneumatic air actuation lines for the air inlet and discharge valves, and the sluggish behavior of the hydraulic oil used in the compactor.

The design specifications stated that the service life of the PTC system should be 40 years. Through observations of equipment degradation and the amount of wear experienced during the first 18 months of operation, it was determined through wear measurements that two system components did not meet this design criteria. The main transport line would fail after 36 years of operation, while the compactor would fail after 38 years. Whereas the compactor can be overhauled, a main transport line failure would create severe and costly problems for many reasons:

- Locating the failed section,
- Excavating in order to reach the section,
- Repairing and/or replacing the failed section,
- Backfilling to cover the section, and
- Providing an alternative refuse collection service during the repair efforts.

ECONOMIC CONCLUSIONS

From the analysis of the data obtained during the monitoring program, it was determined that the PTC system was not, as stated in the design specifications, cost effective. The total annualized cost of the system (i.e., capital, operating, and maintenance) to collect 248.3 tons of refuse per year is $120,021. The annual costs for three alternative conventional systems, which might have been installed, to collect 248 tons of refuse ranged from $26,231 to $74,699. Hence, the PTC system was from 161 to 458 percent more costly than conventional approaches.

The costs for all four refuse collection systems were projected to the year 1995. The annual cost in 1995 for the PTC system to collect 248.3 tons of refuse is about $178,389. The corresponding costs for the three conventional systems ranged from $66,782 to $213,228. Thus, the annual cost for the PTC system was about 0.84 to 2.67 times the costs for the conventional systems.

As previously discussed, the PTC system was not utilized to its design capacity. If the actual refuse loads were six times the loads observed which would then equal the design load criteria, the cost per ton of refuse disposed by the PTC system would be from $99 to $116. The corresponding values for the three alternative conventional systems would range from $104 to $341. Thus, the PTC system could be cost-effective if the refuse loadings at the site approached the design criteria of 1300 to 1600 tons of refuse per year.

The capital costs of the PTC system, which totaled $89,782 per year, accounted for about 75 percent of the annual cost. The major capital expenditures were: (1) the main transport line ($36,751 per year or 31 percent of the annual cost), (2) the equipment space in the CEB ($15,451 per year or 13 percent of the annual cost), and (3) engineering ($12,906 per year or 11 percent of the annual cost). If measures were implemented to reduce the capital cost of the PTC system, especially with the main transport line, equipment space, and engineering, the economics of the system would become more attractive. Two such measures might be a lower cost substitute for the main transport line and placement of the line above ground.

RESIDENT ACCEPTANCE CONCLUSIONS

In general, it can be deduced that both residents and management accepted the PTC system. The acceptance was attributable to: the ease in using the system, relatively few sanitation problems, the infrequent visits by service vehicles, the removal of most of the visible and audible signs associated with refuse collection systems, the disappearance of vermin and rodents, and to other advantages which were intrinsic to the PTC system.

Most of the residents were aware of the capabilities of the system as well as the management's responsibility for the operation of the system. About 98 percent of the residents realized that the site management was responsible for system operations, while 95 percent of the residents were aware that large bulky waste would be collected by contacting the site management. About 66 percent of the residents segregated their refuse into many of the following categories: glass, bulky waste, plastic, food waste, newspapers, and cans. However, there was no policy implemented by the site management for refuse segregation.

The site management accepted the PTC system but felt that many problems associated with the system could have been avoided if the tenants had used the system properly. The management believed that the large maintenance effort could have been substantially decreased if the tenants had not misused the system. However, as resident-related problems occurred, the management took immediate steps to correct the situation by reinforming residents of the regulations for proper use of the PTC system. Specific problems cited by the site management include:

- Residents breaking PTC system components by forcing large, bulky wastes into the chute door;
- Residents causing chute blockages by not pushing refuse all the way down the chute;
- Residents leaving food wastes and moist garbage on charging station floors or in hallways and stairways; and
- Residents improperly wrapping refuse which created unsanitary and unhealthy conditions in discharge valve rooms, especially during periods of operating problems.

ENVIRONMENTAL CONCLUSIONS

Examination of the data showed that the sanitation effects such as litter, cleanliness, odor, and presence of rodents and vermin were minimal. The effort of site personnel, combined with attributes of the PTC system, controlled litter and odor, and this cleanliness kept the vermin population down. Furthermore, it should be noted, that during the entire monitoring program no rodents were observed. The problems with litter, odor, and vermin occurred only during prolonged system downtimes, particularly during hot, humid weather.

Although the internal air of the system had excessive levels of airborne particulates and viable particles, the dust collector effectively removed the matter such that the concentration levels in the system exhaust air were consistently lower than the levels in ambient air. Additionally, the concentration of airborne particles in the system exhaust air never exceeded the Primary Standard for the National Ambient Air Quality Standards for particulate matter which was 3.28×10^{-5} grains per cubic feet. The average values of total airborne particulate matter was 13.74×10^{-5}, 2.11×10^{-5} and 3.97×10^{-5} grains per cubic foot for system internal air, system exhaust air and ambient air, respectively. Thus, the system exhaust air had lower levels of airborne particulates than the ambient air which also complied with the design criteria.

The viable particle concentrations for the system internal air, system exhaust air, and ambient air were 7.3, 3.8, and 5.8 colonies per cubic foot, respectively. The concentration of viable particles in the system exhaust air was lower than in the ambient air. This met the design criteria. In addition, the odor, which was negligible, from the exhaust air was undetected by the residents.

Analysis also showed that the noise produced by the PTC collection activities was generally lower than background noise levels. Much of the noise was isolated from the residential areas by locating many of the noise-producing components in the CEB. Furthermore, the noise attributed to the PTC system never exceeded OSHA requirements. As such, the effects of the noise from the PTC system were limited and not a factor to residents.

The design of the system considered retaining the site aesthetics; hence, most of the PTC system components were located underground, behind walls, or in the CEB. Those components that were visible were made to blend into the site. These measures were most effective in removing the visible signs of the PTC system.

Results from the monitoring program show that there were definite advantages to a reduced number of service vehicle visits to the site to pick up and dispose refuse. These advantages included:

- Less noise,
- Less expense,
- Less tenant awareness,
- Less chance of accidents, and
- Freed service vehicles for other operations.

SECTION III

RECOMMENDATIONS

From observations made during the monitoring program, the data collected, and the analyses of the data, certain recommendations have been made that could improve the efficiency, effectiveness, and economy of the PTC system for future residential applications. These recommendations basically fall into two broad categories, namely design modifications and changes in daily system operations.

One overall recommendation is that in order for the PTC system to be most advantageous, it should be used in high density residential communities and in other areas where there are high refuse loadings. For these applications, the PTC system could be the most economical selection and provide higher levels of service than conventional refuse collection systems.

DESIGN RECOMMENDATIONS

First and foremost, the design loads of refuse should be carefully estimated to insure that the actual loadings of a proposed site would justify the capital costs of a pneumatic trash collection system. This can be achieved by observing the refuse loads of similar nearby residential complexes.

With the existing PTC system, there are no provisions for (1) the collection of bulky refuse that cannot be collected by the system, and (2) an alternative refuse collection service during prolonged system downtimes. Therefore, future designs should consider features to provide an efficient and effective service to handle these provisions.

The design of the existing PTC system had many problems which caused frequent interruptions to collection services and prolonged downtimes. Considerations

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for the design of future PTC system applications should consider methods of resolving the following problems.

- Water infiltration and refuse blockages in the main transport line.
- Design changes for the following system components which were identified as critical for proper system operations.
    - main transport line,
    - programmer,
    - discharge valves,
    - control panel,
    - vertical trash chutes, and
    - compactor.
- Blockages in discharge valves and chutes.
- Proper operation of the container handling system.
- Proper heating of the rooms housing system components.

These problems with the investigated PTC system were due to design inadequacies and caused frequent system malfunctions and prolonged downtimes.

The problem of water infiltration could be solved by placing a water trap and pump at the lowest point in the transport line. The pump should be able to handle solids, such as refuse, as well as liquids.

The observed PTC system had six critical components (the main transport line, the programmer, the discharge valves, the control panel, the vertical trash chutes, and the compactor) which created most of the problems with the system operations. Improvements in the design of these components could benefit in lower downtime costs as well as providing for an improved collection service.

As for refuse blockages in the line, the PTC system was designed and built with access plates at strategic points along the line. These plates allowed equipment to be placed in the line to remove the blockages. However, many of these plates were inaccessible. Future design of PTC systems should consider placing more access plates at locations more convenient for the equipment needed to remove blockages and no further apart than thirty feet.

To alleviate problems with chute blockages, future chutes should be designed without bends and restrictions, and with larger cross-sectional areas. The addition of energy absorbing baffles would also prevent refuse compaction when objects free fall on to loose refuse at the bottom of chutes.

A variety of problems were experienced with blockages in the discharges valves. Future design should consider either improvements in the discharge valves themselves or alternative means for passing refuse from the chutes to the main transport line. Positive suction through the trash chute rather than gravity feed through a discharge valve would improve this situation. Other pneumatic conveying systems have successfully utilized this approach.

Several problems were caused by litter in the discharge valve rooms when site personnel removed litter control devices. By removal of these devices, refuse was not controlled when entering the discharge valves. Because of this, problems arose with operating the discharge valve plate. Further problems were caused by site personnel in their attempts to clean up the litter and repair the discharge valves. Future systems should be designed so that litter and spillage from the chute is more efficiently controlled.

The container handling system used at the site was insufficient, basically due to two problems. One was that the hydraulic lifts could not raise a fully loaded refuse container. The other problem was that the power assisted rollers frequently failed. Future PTC system designs should make certain that the components for the container handling system are properly sized to handle the weight and stress of a fully loaded refuse container.

Unlike the PTC system that was investigated, future systems should take into account the temperatures at which system components best operate. Measures should be incorporated so that the temperatures of rooms housing system components can be maintained at the proper levels. One of the main problems with the system, due to low temperatures, was caused by using outside air for the air inlet valves. This was accomplished by louvers through the exterior walls. Since the rooms where components were located were not heated, cold air entering into the room through the louvers caused component malfunctions through ice formation in pneumatic actuating air lines.

The PTC system would appear to be easily modified for recycling resource materials such as paper, plastics, glass, and metals. Future system applications could consider reclamation of these materials and determine the suitability of this innovation. The economic benefits of recycling would require analysis.

Discharge valve rooms should be designed to be more accessible to site personnel. Better locations would facilitate manual collection services when needed and aid in proper maintenance activities.

One factor that contributed to excessive downtimes with the Jersey City PTC system was the central control panel. The control panel was located in the CEB along with the total energy plant. Since the total energy plant was operated by an outside party, they controlled the access to the CEB. Thus, site personnel had access to the building and the central control panel only when this outside party was present at the site. When system malfunctions occurred after daily work hours or on weekends, site personnel could not gain access to the control panel and thereby start repairs until the outside party arrived at the site. This situation caused needless delays in servicing the system. Future PTC systems should consider placing the central control panel in a more convenient location for all authorized site personnel.

New PTC systems should be designed with new and improved alarm systems. Problems were observed with the annunicator panel used to indicate malfunctioned components. One problem was that some alarms did not operate properly. Another problem which was experienced, was that the same series of alarm lights would occur for different types of malfunctions. This situation contributed to extended system downtime because it was not obvious by the alarm lights which component had malfunctioned.

A problem that also caused long downtimes was that since system components were dependent upon each other for proper operations, when one component malfunctioned the annunciator panel would register this malfunction for a second component. Here again, delays in repairing the system were produced. The delays were due to site personnel looking for malfunctions in properly operating components. Alarm systems for future PTC system applications should be designed so that the problems experienced with the existing alarm system, namely the annunciator panel, could be avoided.

When considering the service life for future PTC systems, requirements for components should be investigated more thoroughly. Analysis of the service life of individual components for the system studied revealed that the main transport line and the compactor would not last for the full 40-year service life.

All of these design recommendations should be considered for future PTC systems. However, it is not enough just to design a better system. Measures should be taken to insure that these new systems meet the design requirements. This would entail detailed inspections of all system components, safety equipment, and other related pieces. Furthermore, inspections and test methods should be implemented to assure proper installation.

OPERATIONAL RECOMMENDATIONS

Pneumatic trash collection systems could operate more effectively and with less wear and problems if users are fully aware of the system capabilities and their responsibilities. Many problems with the PTC system at the Jersey City Operational Breakthrough site were caused by misuse of the system by tenants. Precautions should be taken to insure that users not only are aware of how to properly use the system, but do in fact consistently do so.

Some measures that might be taken to achieve this goal would be:

- A special clause in leases about PTC system operation and use;
- The posting of signs at strategic places promulgating system capabilities and use;
- An indoctrination as to proper system use; and

- A different concept of operation, similar to those used is successfully at some PTC installations. At these installations only site personnel are allowed to charge refuse into the system and charging schedules are set up to preclude overloading of chutes. This concept could effectively be used at Jersey City if site personnel collected and charged refuse into the system.

Future PTC systems should also consider educating personnel responsible for the system in its use, operation, and maintenance. Considerable money, time, and effort can be saved when operating personnel fully understand the system. This can be achieved by conducting indoctrination and training classes, preparing manuals, and by additional measures. This requirement should be included in specifications and quotes for future PTC system applications as part of the design and construction contract.

Preventive maintenance programs for future PTC systems should be a major concern. There was no preventive maintenance program at the site studied. Therefore, there was no way of determining how many problems could have been avoided. With a properly planned and executed preventive maintenance program, the service of the system would be improved. Furthermore, benefits of a good program would be savings in time, labor, and money.

Although the PTC system is fully automated, the human element is still a prominent factor. With better educated system users and operators, the PTC system could more fully attain its expectations.

SECTION IV

DATA COLLECTION

Technical and economic data gathered during the monitoring program of the PTC system are presented in this section. Data were collected on a variety of topics so that detailed analyses could be performed to determine the system feasibility, economy, and effectiveness.

MONITORING PROGRAM

The monitoring program was conducted during the first 18 months of the PTC system operations which dated from July 1, 1974 to December 31, 1975. Observations were made of the daily activities of the system and associated functions as well. These functions included the manpower required to assist the system operations, the malfunctions of the system, the conditions of PTC components, and the management and tenant problems.

An instrumentation package to continuously monitor the PTC system was developed and installed. Various data acquisition components, (delineated in Table 3), were placed at strategic points along the main transport line (see the diagram in Figure 5). All data from these components were recorded on analogue recorders in an instrument panel located in the CEB.

In order to accurately record system operations, instruments were chosen that would best monitor the system performance (i.e., velocity and static pressures, power consumption, and malfunction annunciator signals). The following criteria were used to select the monitoring instruments:

- Compatibility with the system design and configuration as developed by the system suppliers, site planners, and developers.

Table 3. DATA ACQUISITION SYSTEM USED TO MONITOR THE PTC SYSTEM

Component	Model Number	Manufacturer	Accuracy	Remarks
Air velocity tap	Pitot-Venturi Flow Element No. 88578	Taylor Instrument Companies	± 1% of span	Measured the velocity of the air stream at each air inlet valve and directly before the main exhausters.
Differential pressure transducer	Model No. 1151DP	Rosemount Engineering Company	± 0.2 % of range + 0.15% of span	Converted pressure readings at static pressure and air velocity taps to electrical signals.
Main exhauster wattmeter transducer				Provided by the National Bureau of Standards and measured the instantaneous power of the main exhausters.
Analogue recorder	Model 1313JA	Taylor Instrument Companies	0.25% of scale 0.1% sensitivity	Seven strip chart recorders used to document any signals from air velocity taps, differential pressure transducers, main exhauster wattmeter transducers, and malfunction annunciator points.
Malfunction annunciator points				Signal was provided from the malfunction annunciator panel at the central control panel for the PTC system.
Control panel				One separate instrument panel adjacent to the central control panel that housed the analogue recorders.
Pressure calibrator	Model 153S18	Taylor Instrument Companies		Used as a primary standard to calibrate all differential pressure transducers.

- Ease of installation, maintenance, and repair or replacement of the instrument sensor and transducer.

- Reliability and accuracy for obtaining data under field environment for over a full year of operation.

- Ease of calibration and malfunction detection to allow quick checking in the field to identify error signals and recalibration for drift.

As mentioned previously, the components of the instrumentation packaged are described in Table 3. The control panel that housed the analogue strip chart recorders is shown in Figure 3.

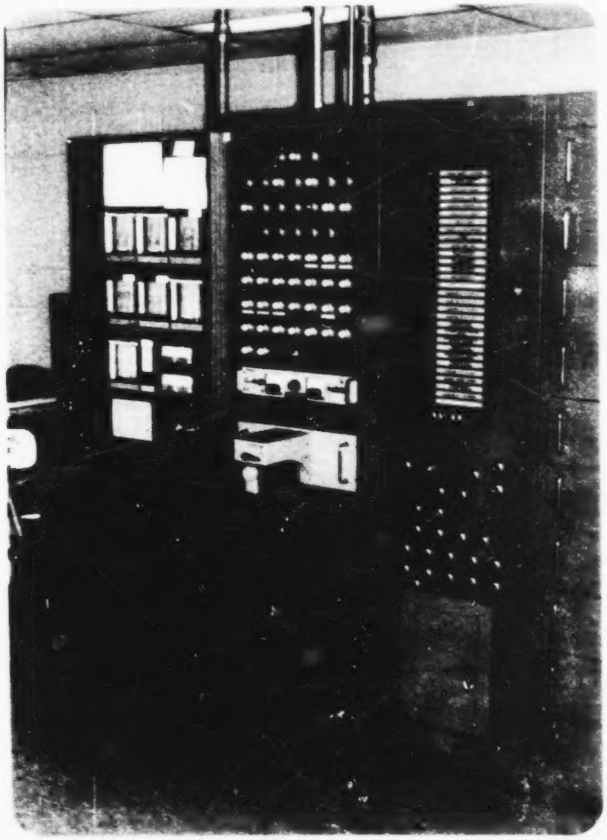


FIGURE 3. Central control panel for the PTC system. The analogue recorders are in the cabinet on the far left.

In addition to the instrumentation package, a daily log book recorded the history of the PTC system activities. Particular problems with the system were cataloged in malfunction report forms. Samples of a page in the daily log book and a malfunction report form are shown in Figures 4 and 5, respectively.

Basically, the monitoring program investigated the PTC system reliability, maintainability, and performance by collecting data on:

- Weight characteristics,
- Daily operations,
- Significant events, and
- Availability.

Weight Characteristics

In order to determine the quantity of refuse collected by the system, the weight of this refuse was measured. This was achieved by the following process. The full refuse container from the compactor was loaded onto a truck and taken to a sanitary landfill. The truck was weighed before and after the disposal of site refuse. The weight differential was the amount of refuse conveyed by the PTC system.

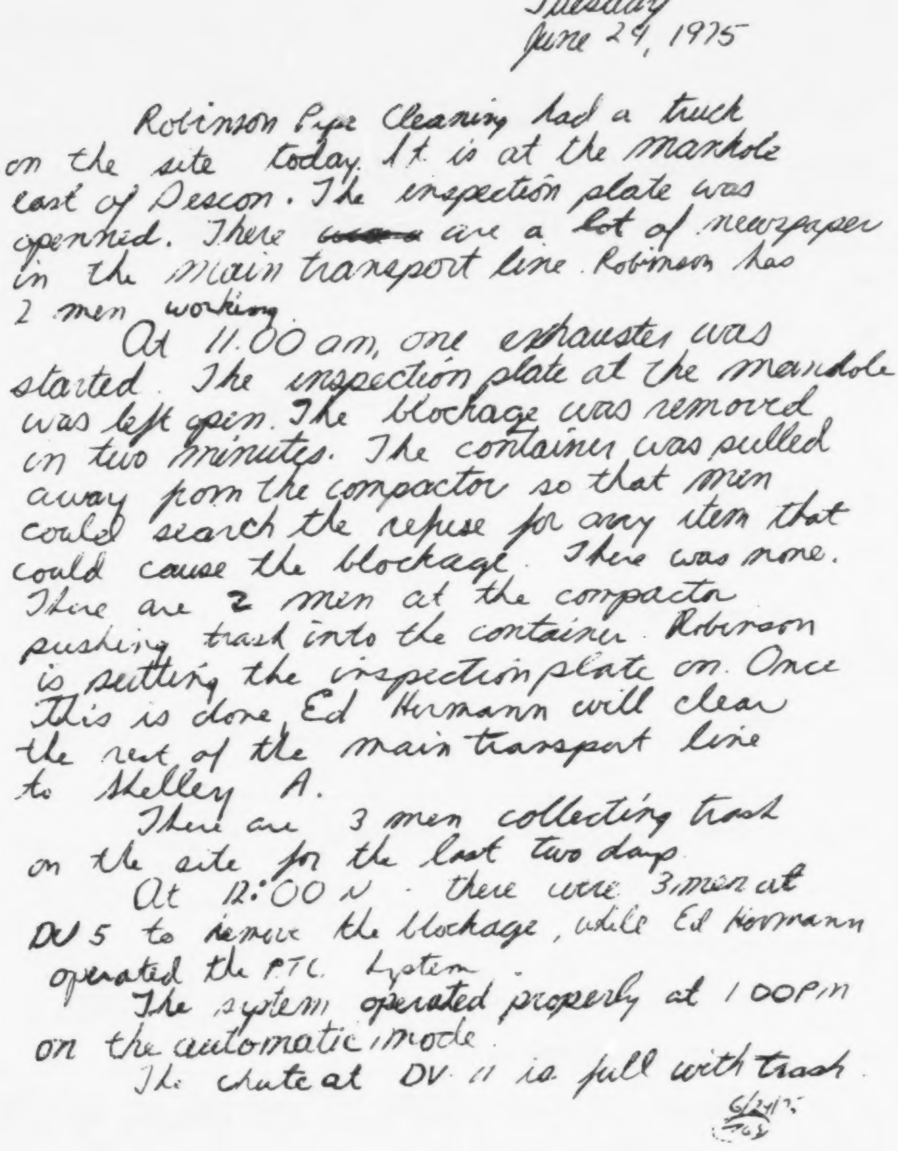
The data for the amount of the refuse conveyed by the PTC system during the monitoring program are presented in Table 4.

Daily Operations

The PTC system was scheduled to operate at various numbers of cycles per day; however, many of these cycles were uncompleted due to the following problems:

- System malfunctions,
- Loss of power from the Total Energy Plant,
- Construction activities, and
- Other actions.

At times, manual cycles were conducted by site personnel to effect certain repairs to the system and to collect refuse during downtime periods. The distribution of completed cycles is presented in Table 5. Table 6 presents the operating schedules for the PTC system during the eighteen month monitoring period.



Tuesday
June 24, 1975

Robinson Pipe Cleaning had a truck on the site today. It is at the manhole east of Descon. The inspection plate was openned. There are a lot of newspaper in the main transport line. Robinson has 2 men working.

At 11.00 am, one exhauster was started. The inspection plate at the manhole was left open. The blockage was removed in two minutes. The container was pulled away from the compactor so that men could search the refuse for any item that could cause the blockage. There was none. There are 2 men at the compactor pushing trash into the container. Robinson is putting the inspection plate on. Once this is done, Ed Hermann will clear the rest of the main transport line to Shelley A.

There are 3 men collecting trash on the site for the last two days.

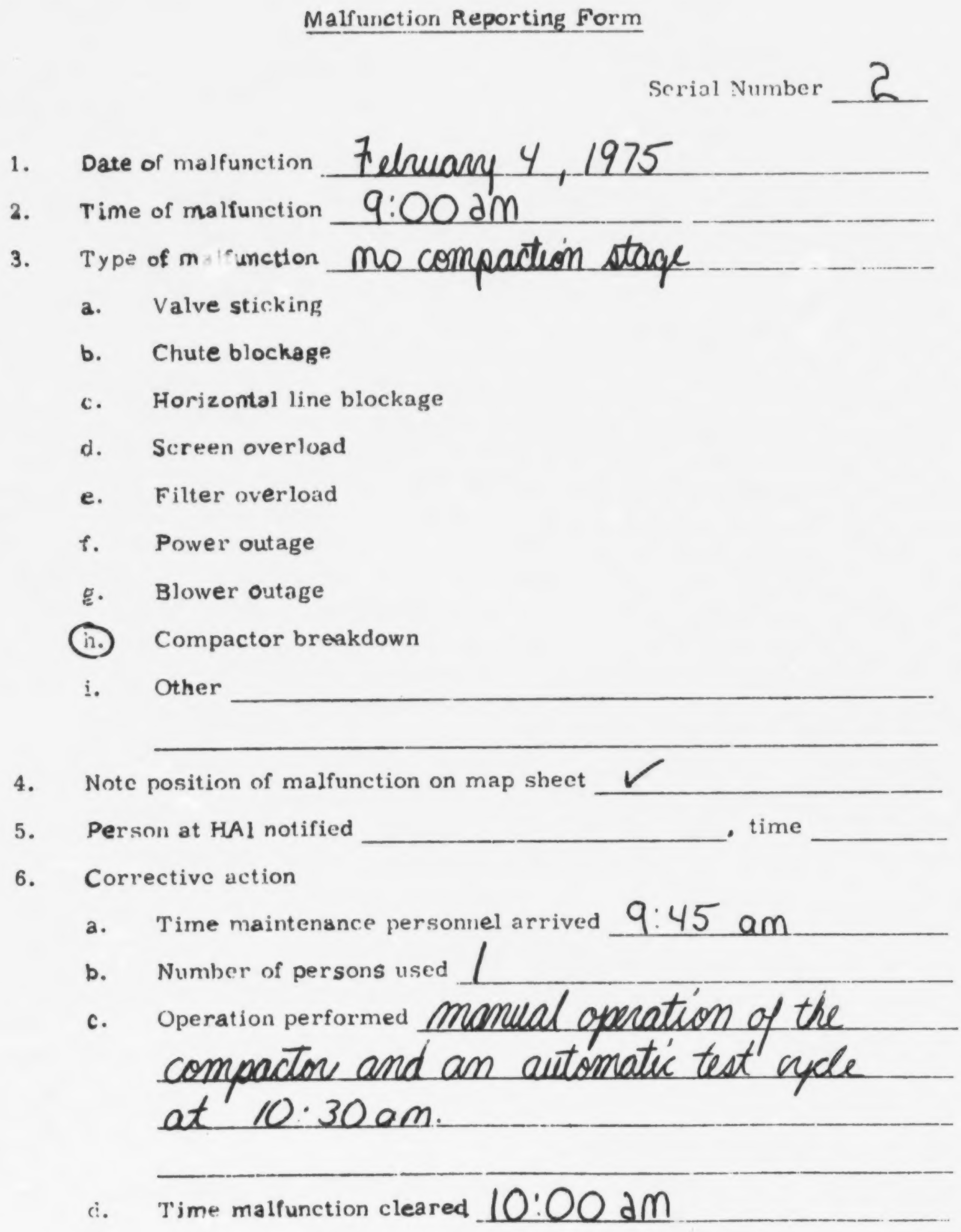
At 12:00 N. there were 3 men at DV 5 to remove the blockage, while Ed Hormann operated the PTC system.

The system operated properly at 1:00 PM on the automatic mode.

The chute at DV 11 is full with trash.

6/24/75

FIGURE 4. One sample page in the daily log book.



Malfunction Reporting Form

Serial Number 2

1. Date of malfunction February 4, 1975

2. Time of malfunction 9:00 am

3. Type of malfunction no compaction stage

   a. Valve sticking

   b. Chute blockage

   c. Horizontal line blockage

   d. Screen overload

   e. Filter overload

   f. Power outage

   g. Blower outage

   [✓ h.] Compactor breakdown

   i. Other

4. Note position of malfunction on map sheet ✓

5. Person at HAI notified ____, time ____

6. Corrective action

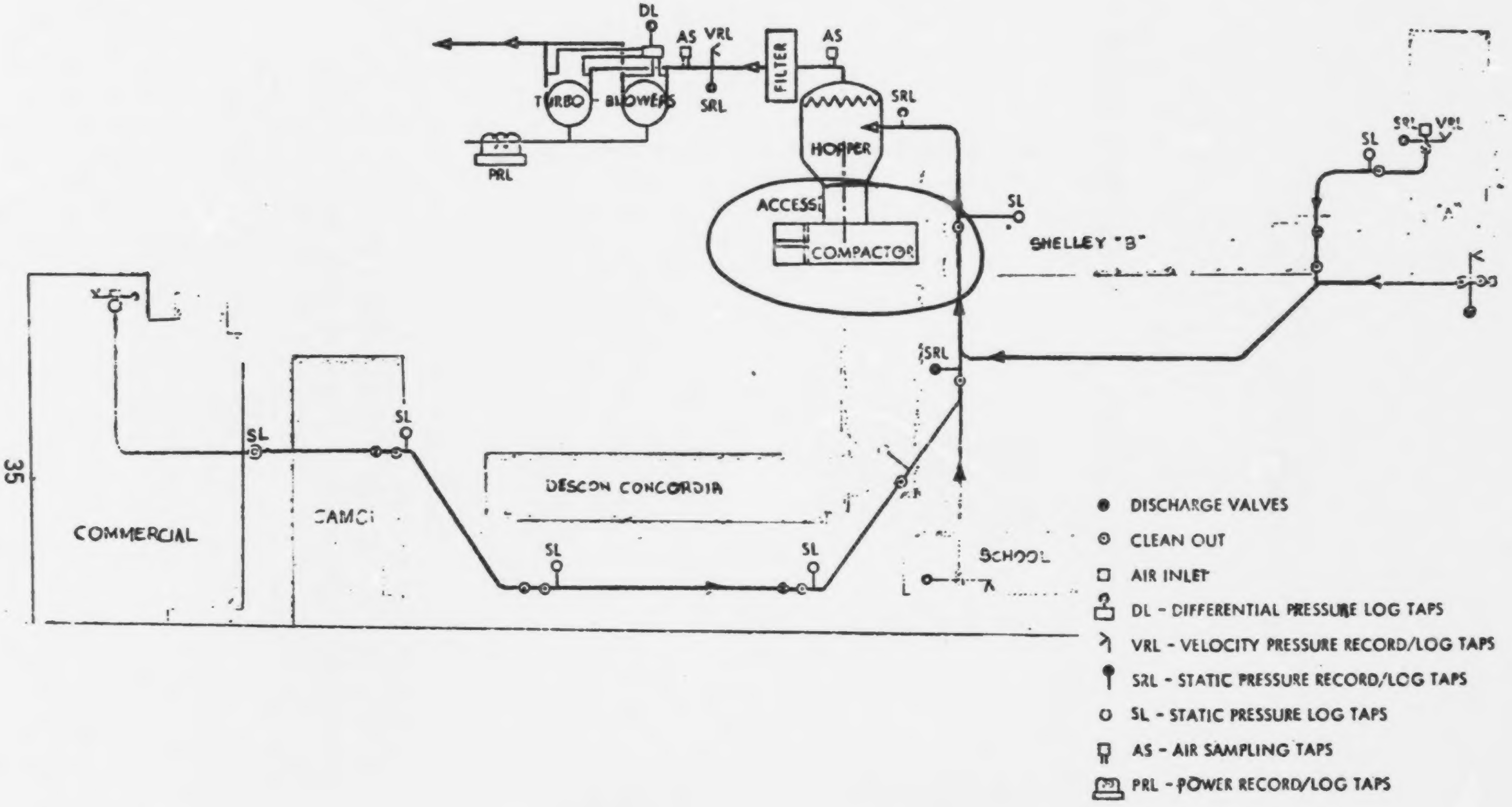
   a. Time maintenance personnel arrived 9:45 am

   b. Number of persons used 1

   c. Operation performed manual operation of the compactor and an automatic test cycle at 10:30 am.

   d. Time malfunction cleared 10:00 am

FIGURE 5. A typical malfunction report.


DL
AS
VRL
FILTER
AS
SRL
TURBO - BLOWERS
SRL
PRL
HOPPER
ACCESS
COMPACTOR
SL
SHELLEY "B"
SL
SRL
VRL
"A"
SRL
SL
SL
SL
SL
COMMERCIAL
CAMCI
DESCON CONCORDIA
SCHOOL
● DISCHARGE VALVES
⊙ CLEAN OUT
□ AIR INLET
DL - DIFFERENTIAL PRESSURE LOG TAPS
VRL - VELOCITY PRESSURE RECORD/LOG TAPS
SRL - STATIC PRESSURE RECORD/LOG TAPS
○ SL - STATIC PRESSURE LOG TAPS
AS - AIR SAMPLING TAPS
PRL - POWER RECORD/LOG TAPS

Jersey City Site

FIGURE 5. (continued)

Table 4. MONTHLY WEIGHT DATA OF SOLID WASTE CONVEYED BY THE PTC SYSTEM

Month		Weight (pounds)	Number of Containers
July[1]	1974		
August		51,500	4[2]
September		46,440	4
October		51,480	8
November		54,040	9
December		49,080	8
January	1975	47,780	5
February		36,380	4
March		42,960	4
April		48,240	4
May		48,220	4
June		43,100	4
July		-0-	-0-[3]
August		36,140	3
September		52,140	5
October		46,060	4
November		46,100	4
December		49,480	4
Total		749,140	78

---

[1] *The containers were not weighed during July 1974.*

[2] *The site personnel collected and disposed bulk waste in the compactor. A portion of the August 1974 weight data contained the bulk waste.*

[3] *A prolonged downtime period was experienced, and there were no container changes during July 1975.*

Table 5. DISTRIBUTION OF AUTOMATIC AND MANUAL MODE PTC SYSTEM CYCLES

Time Interval	Automatic Mode	Manual Mode	Combined Mode
Daily Basis	18	1	19
Annual Basis	6,512	440	6,952
Monitoring Period (Observed Data)	9,768	660	10,428

Significant Events

The history of the PTC system performance is depicted in Figure 6. The significant events shown in this figure are further described in Table 7. As is clearly evident from these presentations, the system experienced prolonged downtime periods which severely limited collection service.

Availability

The data collected on the availability of the PTC system have been presented in diagrams. These diagrams graphically show, in intervals of two hundred scheduled cycles, the ratio of completed cycles to scheduled cycles. For the automatic mode, Figure 7, the system availability averaged 53.6 percent. The system availability for automatic and manual modes, Figure 8, averaged 56.6 percent. The system availability for each month is presented in Table 8.

COMPONENT TEST PROGRAM

A test program was developed to characterize the reliability, maintainability, and performance of the major PTC system components. These results provide detailed information necessary to evaluate the PTC system for effectiveness.

The following experiments comprised the test program:

- Sampling of total airborne particulates -- The relative air quality of the PTC system was compared to the ambient air with respect to dust content by measuring the particulate concentration of system internal air, system exhaust air, and ambient air. Test procedures are given in Appendix A.

Table 6. DAILY SCHEDULES FOR CYCLING THE PTC SYSTEM FROM JULY 1, 1974 TO DECEMBER 31, 1975.

Dates:			
Started	Ended	Cycles/Day	Time
July 1, 1974	August 8	14	7 a.m. to 8 p.m.
August 9	August 21	None[1]	7 a.m. to 8 p.m.
August 22	September 12	14	7 a.m. to 8 p.m.
September 13		5[2]	7 a.m. to 8 p.m.
September 14		14[2]	7 a.m. to 8 p.m.
September 15		11[2]	7 a.m. to 8 p.m.
September 16	December 22	14	7 a.m. to 8 p.m.
December 23		21	7 a.m. to 6 p.m.
December 24, 1974	April 13, 1975	30	7 a.m. to 10 p.m.
April 14		21	7 a.m. to 10 p.m.
April 15	June 4	18	7 a.m. to 11 p.m.
June 5	October 30	17	7 a.m. to 11 p.m.
October 31	November 1	4	7 a.m. to 8 p.m.
November 2	November 5	7	7 a.m. to 11 p.m.
November 6	November 10	7	7 a.m. to 10 p.m.
November 11	November 13	9	7 a.m. to 11 p.m.
November 14	November 17	24	1 a.m. to 12 p.m.
November 18	November 23	15	7 a.m. to 9 p.m.
November 24		10	8 a.m. to 10 p.m.
November 25	November 28	7	8 a.m. to 9 p.m.
November 29	December 3	15	8 a.m. to 10 p.m.
December 4	December 16	7	8 a.m. to 9 p.m.
December 17	December 21	11	8 a.m. to 11 p.m.
December 22	December 31, 1975	15	8 a.m. to 10 p.m.

[1] *A plant failure occurred in the Total Energy System, and the PTC system was turned off.*

[2] *Tests were performed on the Total Energy System, which changed the number of scheduled cycles for the PTC system.*

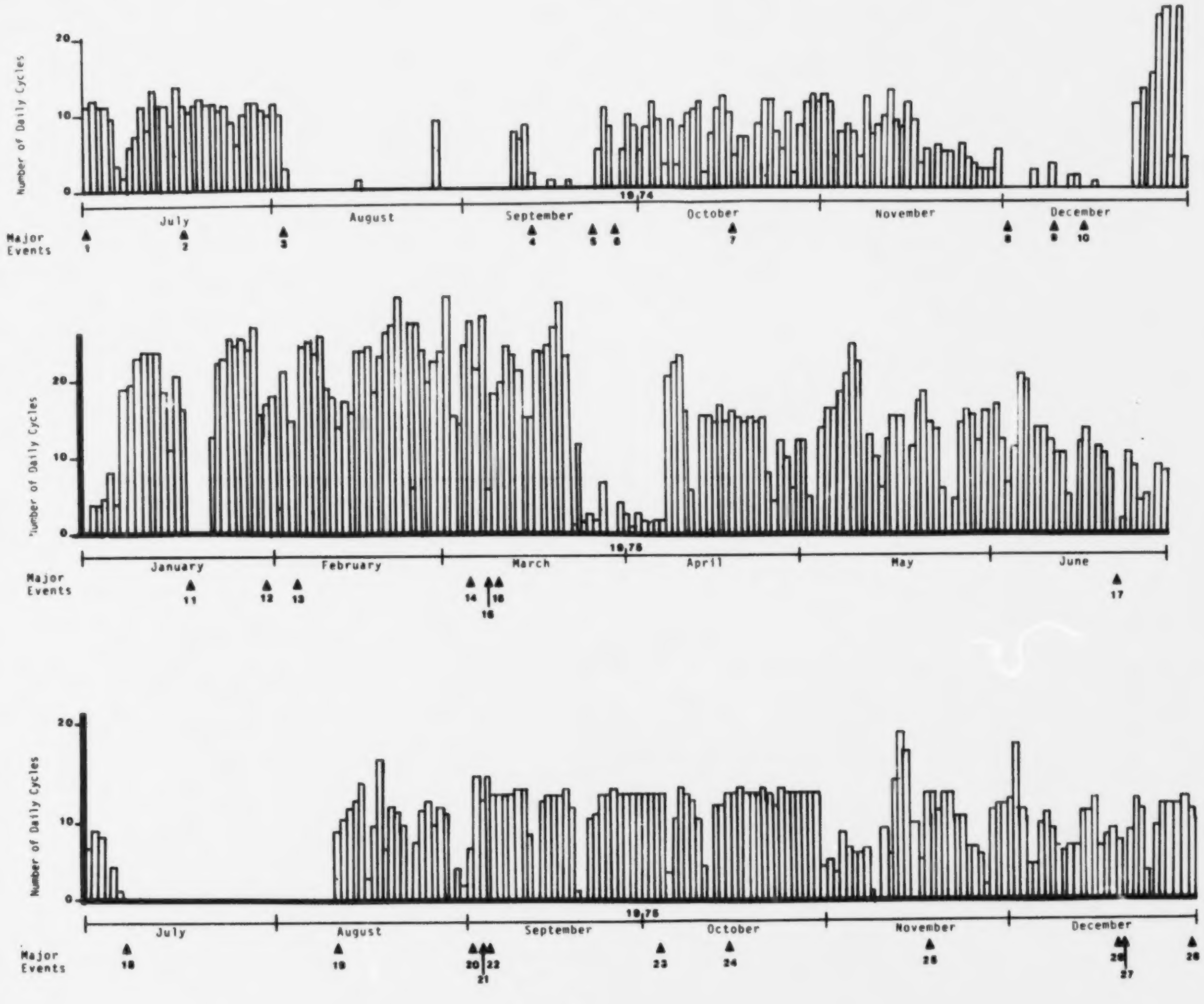
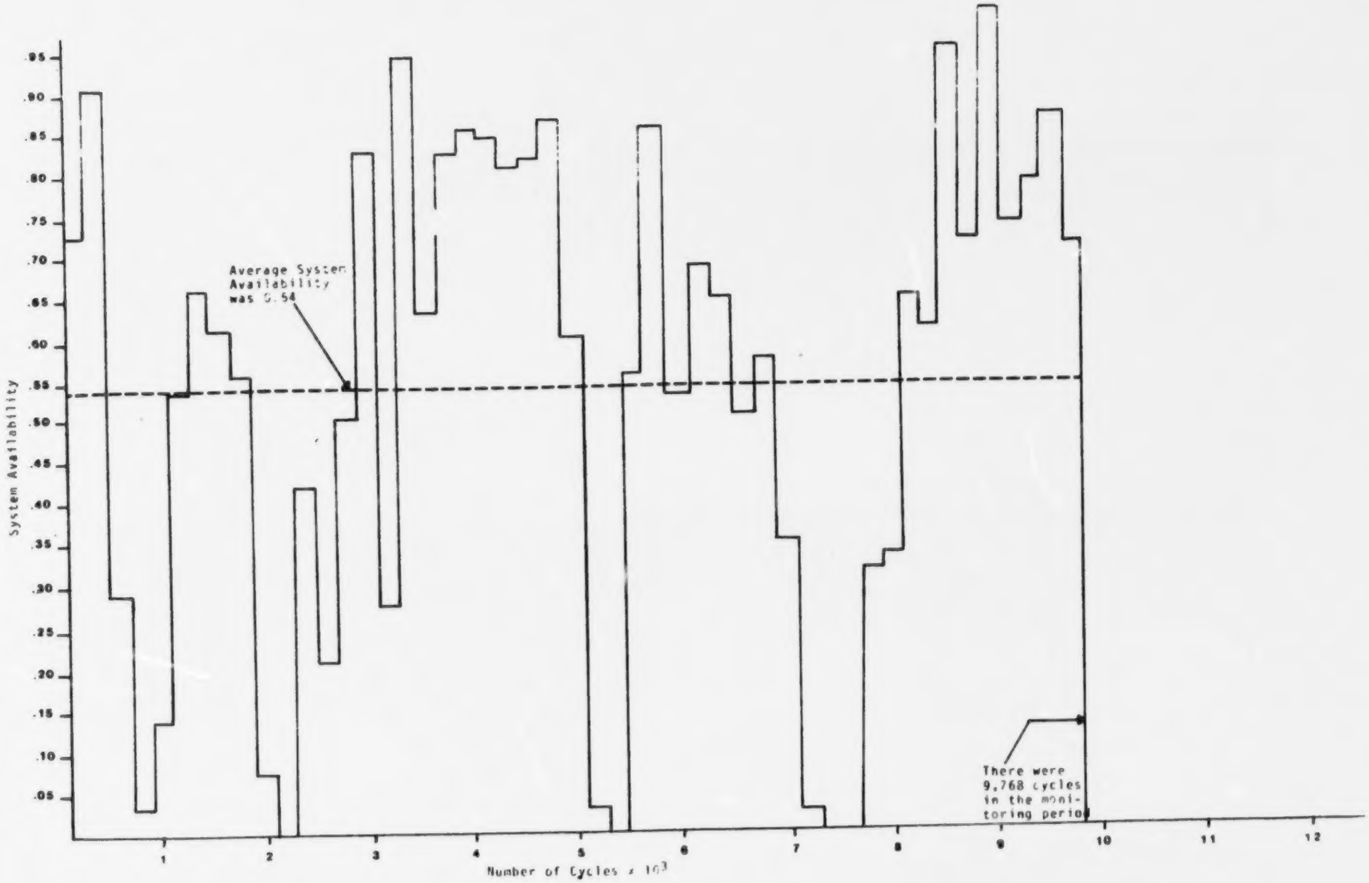


FIGURE 6. Daily number of completed cycles for the PTC system from July 1, 1974 to December 31, 1975.



Average System Availability was 0.54

There were 9,768 cycles in the monitoring period

FIGURE 7. PTC system availability based on automatic operations.

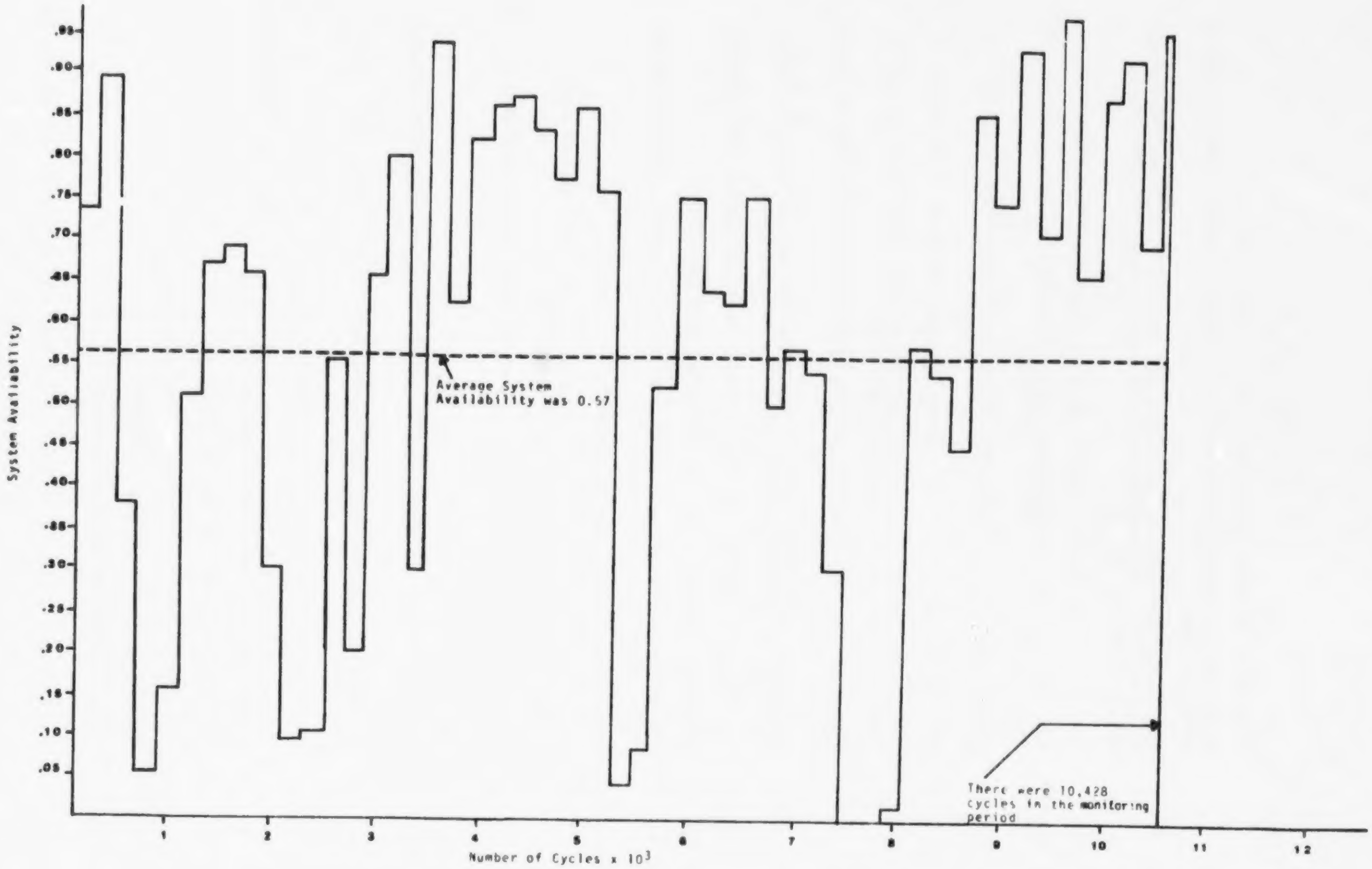


FIGURE 8. PTC system availability based on combined operations (automatic and manual mode cycles).

Table 7. HISTORY OF SIGNIFICANT EVENTS OF THE PTC SYSTEM

Number	Date	Description of Event
1	July 1, 1974	First day of PTC system operations and monitoring program
2	July 17, 1974	Problems develop with paper and plastic bags blocking hopper screen and reducing system air flow.
3	August 3, 1974	Total Energy Plant experiences complete loss of power which is not repaired until August 20, 1974. Water infiltration problems in the main transport line develop during this period.
4	September 15, 1974	Total Energy Plant is shut down for two days, and PTC system is inoperative.
5	September 23, 1974	Main transport line blockage between Descon Concordia and Camci is noticed. PTC service to residents in Camci is impossible.
6	September 27, 1974	Total Energy Plant experiences complete loss of power during a PTC system collection cycle.
7	October 17 & 18, 1974	NBS conducts load tests on Total Energy Plant and PTC system is turned off.
8	December 1, 1974	Fire in trash chute at Descon Concordia, and sprinkler system did not activate. Tenant calls fire department to extinguish fire.
9	December 9, 1974	Main transport line blockage which started before September 23, 1974 is finally cleared.
10	December 13-19, 1974	Installation of discharge valves at the Descon deck locations and a new hopper screen at the collection hopper. PTC system is turned off.
11	January 14-17, 1975	Low ambient room temperatures create hydraulic oil flow problems for compactor.
12	January 30, 1975	High temperature alarm cable for main exhauster number 2 burns.
13	February 4-7, 1975	Low ambient room temperatures creates ice blockages in pneumatic activating air Shelley A.
14	March 5, 1975	Total Energy Plant is down for two hours.
15	March 9, 1975	Programmer problems develop. Fixed September 3, 1975 which created severe operating problems from March 23 to April 7, 1975.
16	March 11, 1975	Alarm goes off in Total Energy Plant during the night and site personnel turn off main switches to exhausters.
17	June 23-24, 1975	Main transport line blockage is removed.
18	July 7 to August 8, 1975	Power failure of Total Energy Plant and PTC system after severe lighting storm.
19	August 11 to September 3, 1975	Daily starting problems with main exhauster and compactor, which are related to programmer.
20	September 1-3, 1975	Main transport line blockage stops refuse collection system.
21	September 3, 1975	Defective power supply for programmer is replaced, and during test procedures the main transport line blockage is removed.
22	September 4, 1975	Main transport line blockage is removed.
23	October 3, 1975	Total Energy Plant is shut down for 50 minutes.
24	October 14, 1975	Main transport line blockage is removed.
25	November 16 & 17, 1975	Main transport line blockage is removed.
26	December 19, 1975	Low room temperatures at Shelley A freezes pneumatic activating air lines for PTC equipment.
27	December 20, 1975	Hopper gate opens slowly and creates system malfunctions.
28	December 31, 1975	PTC system is turned off for 3 hours during the installation of PTC equipment at the school, and final day of monitoring program.

Table 8. PTC MONTHLY SYSTEM AVAILABILITY IN TERMS OF SCHEDULED VERSUS COMPLETED AUTOMATIC CYCLES FROM JULY 1, 1974 TO DECEMBER 31, 1975

Month		Scheduled Cycles	Completed Cycles	Availability
July	1974	434	357	0.823
August		241	34	0.141
September		408	74	0.181
October		427	265	0.621
November		420	176	0.419
December		569	126	0.221
January	1975	929	526	0.566
February		837	670	0.800
March		921	561	0.609
April		698	335	0.480
May		558	346	0.620
June		514	251	0.488
July		527	19	0.036
August		527	131	0.249
September		510	370	0.725
October		512	441	0.861
November		371	274	0.739
December		365	287	0.786
Total		9,768	5,234	
Average Availability				0.537

- Sampling of viable particles -- Similar to the previously described experiment, the biological activity in the air of the PTC system was determined by measuring viable particles in the system air, system exhaust air, and ambient air. Test procedures are given in Appendix B.

- Solid waste characterization -- The site refuse, as conveyed by the PTC system, was characterized by composition, density, and moisture content. Test procedures are given in Appendix C.

- Load profile -- The refuse collected by the PTC system was weighed for every cycle for an entire week to determine peak loads, trends, and usage patterns. Test procedures are presented in Appendix D.

- Load capacity -- The transport velocities of test samples, varying in density, were measured to establish the densest loading which could be collected successfully by the system. Test procedures are given in Appendix E.

- Main exhauster power consumption -- The power consumed by the main exhausters during typical operations was measured. Test procedures are presented in Appendix F.

- Optimum scheduling -- Modified operating schedules were tested to investigate the system performance for a reduced number of daily cycles. Test procedures are given in Appendix G.

- Noise level measurements -- Noise levels associated with the PTC collection activities were compared to background noise levels. Test procedures are reported in Appendix H.

- Life cycle estimates -- Extensive wear, weekly velocity, and static pressure tests were conducted to predict the service life of the PTC system. Initial characterization tests were performed before the monitoring program to determine the original condition of the system. Weekly velocity and static pressure tests were conducted to observe the degradation of the system during the monitoring program. Post monitoring period characterization tests were performed to determine the amount of wear experienced during the program. The system components investigated were the:

- Main transport line,
- Discharge valv[illegible],
- Collection hopper,
- Dust collector,
- Compactor, and
- Chute charging stations.

The test procedures are given in Appendix I.

Air Sampling Tests

Sampling of air pollutant levels for the PTC system air and ambient air were performed on the following dates:

- February 24 to 28, 1975,
- July 23 to 27, 1975, and
- January 5 to 9, 1976.

Seasonal affects were considered by conducting the tests in summer and winter.

The tests for the total airborne particulates and viable particles were conducted to observe air pollutant problems attributed to the PTC system. The three sampling locations used in these tests were:

- System air inside the collection hopper,
- System exhaust air at the exhaust vent, and
- Ambient air at a remote outdoor location.

The levels of total airborne particulates were measured by high volume samplers as depicted in Figures 9, 10, and 11. The exhaust air and ambient air were sampled continuously. The system air inside the collection hopper was sampled between PTC cycle operations. The results for the particulate sampling tests are reported in Table 9.

FIGURE 9. Sampling of airborne particulates at the collection hopper by a high volume sampler.

FIGURE 10. Sampling of airborne particulates of the system exhaust air by a high volume sampler.

FIGURE 11. Sampling of airborne particulates in ambient air by a high volume sampler.

The sampling of viable particles was conducted with an Andersen 2000 six-stage sampler. An independent laboratory performed the media preparation, incubation, and colony counts. Figures 12 and 13 show viable particle sampling of the collection air and ambient air. Figure 14 shows a typical stage after the incubation period. The results of the tests are presented in Table 10.

Refuse Characterization Tests

The site refuse collected by the PTC system was characterized by composition, density, and moisture content. These tests were carried out during the same time periods as the air sampling tests. The refuse was manually separated into the following ten categories:

- Paper,
- Fines (any refuse that passes through a one-inch sieve),
- Food,
- Metal,
- Plastic,
- Glass,
- Textiles,
- Wood,
- Rocks, and
- Yard wastes.

The refuse was weighed in trash cans and sorted into the ten categories as shown in Figures 15, 16, and 17. The composition of the solid waste is reported in

Table 9. CONCENTRATIONS OF TOTAL AIRBORNE PARTICULATES

Date		Ambient Air (10^5 x grains/cu ft)	Hopper Air (10^5 x grains/cu ft)	Exhaust Air (10^5 x grains/cu ft)
Monday	2/24/75	2.51	4.73[1]	1.05
Tuesday	2/25/75	3.56	4.73[1]	1.45
Wednesday	2/26/75	5.38	4.73[1]	2.18
Thursday	2/27/75	4.05	4.73[1]	1.41
Friday	2/28/75	4.11	4.73[1]	1.26
Average		3.92	4.73[1]	1.47
Monday	6/23/75	5.03	6.10	4.65
Tuesday	6/24/75	6.04	6.38	3.52
Wednesday	6/25/75	3.33	6.11	2.08
Thursday	6/26/75	3.66	2.56	1.75
Friday	6/27/75	4.19	9.21	1.70
Average		4.45	6.07	2.74
Monday	1/5/76	3.24	5.86	2.29
Tuesday	1/6/76	4.31	7.10[2]	2.32
Wednesday	1/7/76	4.64	130.00[2]	2.95
Thursday	1/8/76	2.08	3.81	1.43
Friday	1/9/76	3.45	5.32	1.58
Average		3.54	30.42	2.11

---

[1] *One filter paper was used for the entire five day period.*

[2] *Fine dust particles similar to green paint dye were in the collection hopper which may account for the high particulate level.*

FIGURE 12. Viable particle sampling of the collection hopper air.

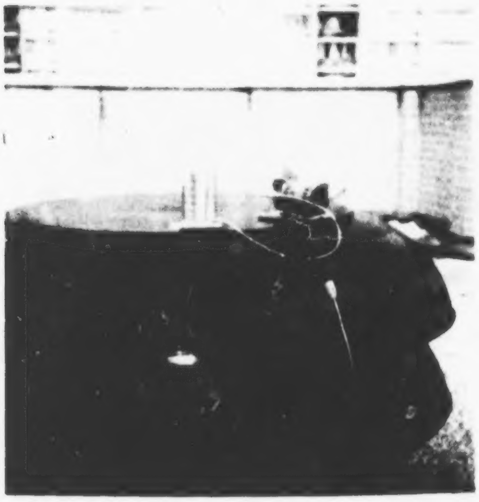


FIGURE 13. Viable particle sampling of ambient air.

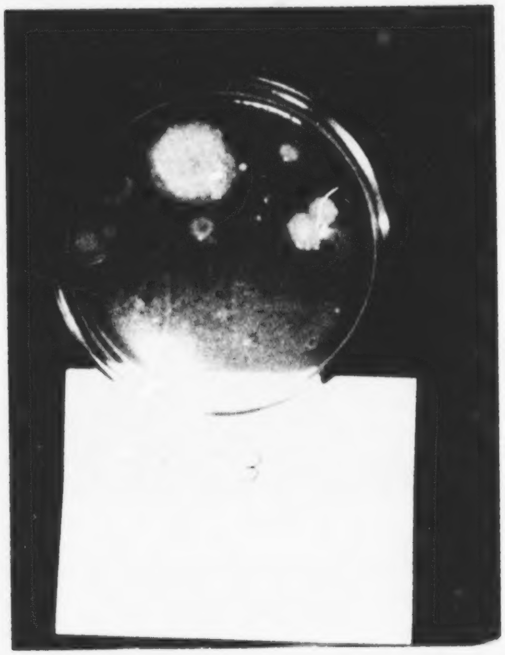


FIGURE 14. A typical stage from the viable particle sampling test after the incubation period showing colonies.

FIGURE 15. Sample of refuse being collected during the solid waste characterization test.

Table 10. VIABLE PARTICLE CONCENTRATIONS

Date	Ambient Air (Colonies/cu ft)	Collection Hopper (Colonies/cu ft)	System Exhaust (Colonies/cu ft)
Monday 2/24/75	0.8	3.9	1.5
Tuesday 2/25/75	0.7	4.2	0.5
Wednesday 2/26/75	3.2	3.9	3.3
Thursday 2/27/75	0.6	4.9	1.4
Friday 2/28/75	8.3	5.4	4.9
Average	2.7	4.5	2.3
Monday 6/23/75	3.0	5.3	3.1
Tuesday 6/24/75	1.7	3.9	1.7
Wednesday 6/25/75	14.5	10.0	7.1
Thursday 6/26/75	20.6	19.3	4.9
Friday 6/27/75	10.2	3.0	12.4
Average	10.0	8.3	5.8
Monday 1/5/76	3.1	3.0	2.3
Tuesday 1/6/76	7.7	7.5	6.0
Wednesday 1/7/76	1.7	4.1	1.6
Thursday 1/8/76	1.3	2.7	1.0
Friday 1/9/76	9.1	27.9	5.7
Average	4.6	9.0	3.3

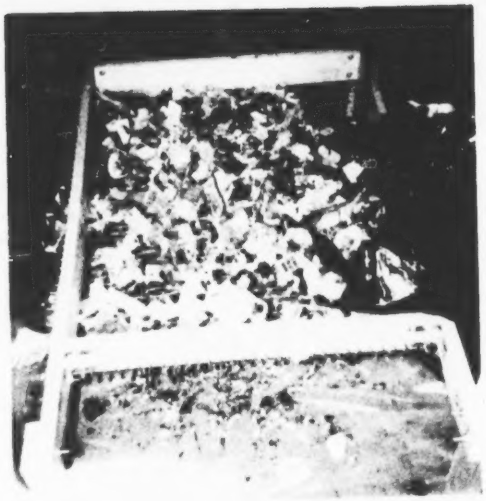


FIGURE 16. Sieve used to separate the refuse. All refuse which fell through the sieve was classified as fines.

FIGURE 17. Refuse was manually sorted for the solid waste characterization test.

Tables 11, 12, and 13. The density of the refuse samples is shown in Table 14 and the moisture content of the samples is presented in Table 15.

Load Profile Test

The load profile test documented the daily demand of the PTC system. It was conducted for one week from September 26 to October 3, 1975. The weight of the transported refuse for every cycle was recorded. A platform was built to detain the refuse as the compactor ram pushed it out of the compactor unit as shown in Figure 18. The refuse was weighed as seen by the method shown in Figure 19. The results are presented in Table 16. The data for the first two days were biased by water infiltration in the main transport line.

The data show that there are two distinct load profiles; one for weekdays and another one for the weekend. These trends are shown graphically in Figure 20.

Load Capacity Test

Load capacity test was performed on June 9 and 10, 1975 and on December 2, 1975. The results of this test determined the transport velocities of refuse samples varying in density, and the maximum limit in density for refuse that may be successfully conveyed by the PTC system.

Two kinds of refuse samples were used in the test. Low density loads simulated typical residential solid waste. High density loads determined the upper boundary in density of those items which could be successfully conveyed. The elapsed time and density

Table 11. COMPOSITION BY WEIGHT OF REFUSE SAMPLES COLLECTED FROM FEBRUARY 24 THROUGH 28, 1975

Category[1]	Monday 2/24/75		Tuesday 2/25/75		Wednesday 2/26/75		Thursday 2/27/75		Friday 2/28/75		Five-Day Average	
	Weight	%	Weight	%	Weight	%	Weight	%	Weight	%	Weight	%
Paper	48.0 lb	48.8	53.0 lb	29.4	114.0 lb	60.3	78.4 lb	47.2	56.6 lb	45.5	70.0 lb	46.2
Fines	15.0	15.3	54.0	30.0	28.0	14.8	36.2	21.8	31.8	25.5	33.0	21.8
Food	21.0	21.4	46.0	25.6	22.0	11.6	22.3	13.4	17.8	14.3	25.8	17.0
Metal	10.2	10.4	15.5	8.6	6.3	3.3	17.3	10.4	10.9	8.8	12.0	7.9
Plastic	2.0	2.0	7.3	4.0	5.2	2.8	5.5	3.3	6.2	5.0	5.2	3.4
Glass	1.1	1.1	1.2	0.7	3.0	1.7	1.0	0.6	0.0	0.0	1.3	0.9
Textiles	1.0	1.0	2.0	1.1	9.5	5.0	5.5	3.3	1.1	0.9	3.8	2.5
Wood	0.0	0.0	1.0	0.6	1.0	0.5	0.0	0.0	0.0	0.0	0.4	0.3
Totals[2]	98.3	100.0	180.0	100.0	189.0	100.0	166.2	100.0	124.4	100.0	151.5	100.0

[1] *There were no rocks or yard waste in the refuse samples.*

[2] *The total weight collected during the test period was 757.9 pounds.*

Table 12. COMPOSITION BY WEIGHT OF REFUSE SAMPLES COLLECTED FROM JUNE 23 THROUGH 27, 1975

	Monday 6/23/75		Tuesday 6/24/75		Wednesday 6/25/75		Thursday 6/26/75		Friday 6/27/75		Five-Day Average	
Category[1]	Weight	%	Weight	%	Weight	%	Weight	%	Weight	%	Weight	%
Paper	171.4 lb	55.1	143.1 lb	52.3	199.1 lb	62.8	173.0 lb	57.6	166.6 lb	54.7	170.6 lb	56.6
Fines	59.4	19.1	57.3	20.9	42.5	13.4	34.3	11.4	52.5	17.3	49.2	16.3
Food	31.5	10.1	32.8	11.9	28.5	9.0	38.4	12.8	31.0	10.2	32.5	10.8
Metal	18.2	5.9	17.7	6.5	20.7	6.5	15.0	5.0	16.0	5.3	17.5	5.8
Plastic	11.5	3.7	11.1	4.1	7.8	2.5	9.2	3.1	14.0	4.6	10.7	3.6
Glass	10.7	3.4	8.5	3.1	8.3	2.6	23.8	7.9	19.2	6.3	14.1	4.7
Textiles	8.3	2.7	3.3	1.2	10.0	3.2	6.5	2.2	4.0	1.3	6.4	2.1
Yard Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1
Totals[2]	311.0	100.0	273.0	100.0	316.9	100.0	300.2	100.0	304.3	100.0	301.2	100.0

---

[1] *There were no rocks or wood in the refuse samples.*
[2] *The total weight collected during the test period was 1505.2 pounds.*

Table 13. COMPOSITION BY WEIGHT OF REFUSE SAMPLES COLLECTED FROM JANUARY 5 THROUGH 9, 1976

Category[1]	Monday 1/5/76		Tuesday 1/6/76		Wednesday 1/7/76		Thursday 1/8/76		Friday 1/9/76		Five-Day Average	
	Weight	%	Weight	%	Weight	%	Weight	%	Weight	%	Weight	%
Paper	144.8 lb	44.1	159.0 lb	55.6	173.9 lb	59.7	90.2 lb	51.7	128.0 lb	49.4	139.2 lb	52.0
Fines	113.6	34.6	47.8	16.7	46.7	16.0	40.0	22.9	48.1	18.6	59.2	22.1
Food	28.8	8.8	36.5	12.8	22.7	7.8	19.6	11.2	35.5	13.7	28.6	10.7
Metal	19.4	5.9	18.0	6.3	14.6	5.0	12.2	7.0	17.6	6.8	14.4	6.1
Plastic	10.8	3.2	13.0	4.5	13.0	4.5	3.8	2.2	9.2	3.5	10.0	3.7
Glass	8.8	2.7	6.4	2.2	9.0	3.1	2.8	1.6	10.7	4.1	7.5	2.8
Textiles	2.2	0.7	4.2	1.5	10.3	3.5	4.1	2.4	10.1	3.9	6.2	2.3
Wood	0.0	0.0	1.0	0.4	1.2	0.4	1.7	1.0	0.0	0.0	0.8	0.3
Totals[2]	328.4	100.0	285.9	100.0	291.4	100.0	174.4	100.0	259.2	100.0	267.9	100.0

[1] *There were no rocks or yard waste in the refuse samples.*

[2] *The total weight collected during the test period was 1339.3 pounds.*

Table 14. DENSITY OF SOLID WASTE SAMPLED

Date		Weight of Sample	Volume of Sample	Density	Density (Adjusted)[1]
Monday	2/24/75	100.25 lb	44.2 cu ft	2.26 lb/cu ft	1.13 lb/cu ft
Tuesday	2/25/75	613.65	210.8	2.91	1.46
Wednesday	2/26/75	202.00	75.3	2.68	1.34
Thursday	2/27/75	174.15	72.3	2.41	1.21
Friday	2/28/75	133.75	45.2	2.95	1.48
Average		244.70	89.56	2.73	1.37
Monday	6/23/75	311.0 lb	88.2 cu ft	3.53 lb/cu ft	1.77 lb/cu ft
Tuesday	6/24/75	273.8	64.2	4.26	2.13
Wednesday	6/25/75	316.9	64.2	4.94	2.47
Thursday	6/26/75	300.2	76.2	3.94	1.97
Friday	6/27/75	304.3	88.7	3.45	1.73
Average		301.2	76.2	3.95	1.98
Monday	1/5/76	328.4 lb	92.2 cu ft	3.56 lb/cu ft	1.78 lb/cu ft
Tuesday	1/6/76	285.9	88.2	3.24	1.62
Wednesday	1/7/76	291.4	76.2	3.82	1.91
Thursday	1/8/76	174.4	48.1	3.63	1.82
Friday	1/9/76	259.2	68.2	3.80	1.90
Average		267.9	74.6	3.59	1.80

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[1] *In the sample collection procedure, paper was packed into a container at about a 2 to 1 compaction ratio; therefore, the density figures were adjusted to reflect the uncompacted condition.*

Table 15. MOISTURE CONTENT OF SOLID WASTE SAMPLED

Date	Weight Before Drying	Weight After Drying	Moisture Content
Monday 2/24/75	5.25 lb	3.37 lb	35.8%
Tuesday 2/25/75	6.84	4.66	31.9
Wednesday 2/26/76	8.16	6.05	25.9
Thursday 2/27/75	7.43	5.11	31.2
Friday 2/28/75	7.62	4.60	39.6
Average	7.06	4.76	32.6
Monday 6/23/75	4.03 lb	2.87 lb	28.8%
Tuesday 6/24/75	5.46	4.12	24.6
Wednesday 6/25/75	5.09	3.29	35.3
Thursday 6/26/75	4.51	2.38	47.2
Friday 6/27/75	6.48	4.46	31.1
Average	5.11	3.42	33.1
Monday 1/5/76	6.56 lb	4.62 lb	29.6%
Tuesday 1/6/76	4.04	3.16	21.9
Wednesday 1/7/76	1.65	1.40	15.1
Thursday 1/8/76	3.70	2.63	28.7
Friday 1/9/76	3.94	3.18	19.1
Average	3.98	3.00	24.6

FIGURE 18. Platform and equipment used to weigh refuse for load profile test.

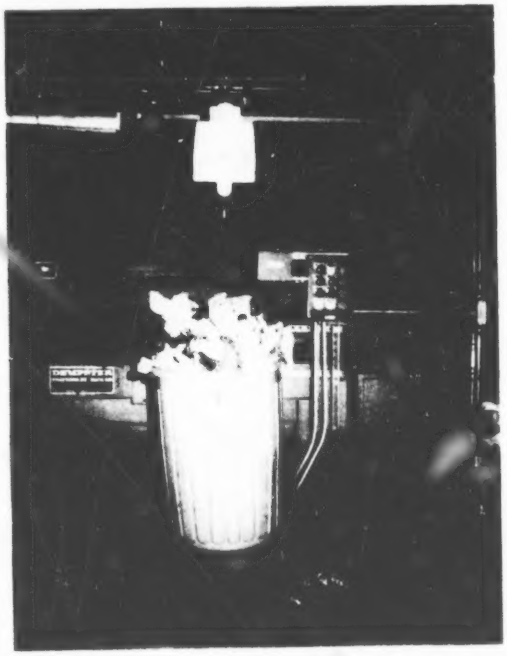

FIGURE 19. One sample of refuse weighed during the load profile test.

Table 16. RESULTS OF THE LOAD PROFILE TEST

Time of Cycle	Friday[2] 9/26/75	Saturday[2] 9/27/75	Sunday 9/28/75	Monday 9/29/75	Tuesday 9/30/75	Wednesday 10/1/75	Thursday 10/2/75	Friday 10/3/75	Average
7 AM		200.4 lb	111.0 lb	133.4 lb	138.0 lb	71.9 lb	52.2 lb	76.9 lb	112.0 lb
8 AM		75.6	18.3	40.1	21.9	51.8	24.7	34.6	38.1
9 AM		139.0	110.5	43.9	197.4	143.9	120.1	40.5	113.6
10 AM		285.0	202.4	57.4	79.3	109.3	69.6	36.1	119.9
11 AM		265.2	152.5	211.1	36.3	32.5	83.8	160.8	134.6
12 Noon		447.5	120.4	239.5	48.0	76.0	39.1	79.1	149.9
1 PM		545.2	204.6	160.8	66.7	66.9	97.8	83.7	175.1
2 PM		351.1	156.2	69.9	60.4	78.4	79.3	58.8	122.0
3 PM	64.0 lb	205.6	137.5	62.4	102.3	32.3	55.1		94.2
4 PM	85.2	167.0	134.0	104.4	102.7	72.8	54.3		102.9
5 PM	84.8	338.5	109.5	71.3	71.0	81.7	65.0		117.4
6 PM	144.1	268.8	135.7	98.6	78.2	115.2	94.8		133.6
7 PM	162.1	195.5	166.2	122.5	121.5	134.4	138.9		148.7
8 PM	226.8	225.7	146.6	112.2	177.8	124.4	175.6		169.9
9 PM	160.2	136.8	99.6	131.5	125.8	126.8	127.0		129.7
10 PM	163.1	113.9	119.3	126.8	75.0	99.1	92.2		112.8
11 PM	121.4	80.3	126.4	76.0	75.3	81.6	65.1		89.4
Daily Total	1,211.7 (1,72.2)[1]	4,041.1	2,250.7	1,861.8	1,577.6	1,499.0	1,434.6	570.5 (1,782.2)[1]	2,063.9
Density	9.37 lb/ft^3	9.65 lb/ft^3	5.40 lb/ft^3	4.94 lb/ft^3	5.04 lb/ft^3	4.85 lb/ft^3	4.65 lb/ft^3	3.95 lb/ft^3	5.86 lb/ft^3[4]
Density (Adjusted)[3]	4.69 lb/ft^3	4.83 lb/ft^3	2.70 lb/ft^3	2.47 lb/ft^3	2.52 lb/ft^3	2.43 lb/ft^3	2.33 lb/ft^3	1.98 lb/ft^3	2.93 lb/ft^3[5]

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[1] *Total for Friday of 1,782.2 lb is sum of collection from 3 PM to 11 PM on 9/26/75, and collection from 7 AM to 2 PM on 10/3/75.*

[2] *Moisture content of refuse collected from 6 PM on 9/26/75 to 7 PM on 9/27/75 was much higher than normal, probably due to leakage into the transport pipe from heavy rain on Friday, 9/26/75. Weights should be reduced by approximately 50 percent to account for the excess moisture.*

[3] *In the sample collection procedure, paper was packed into a container at about a 2 to 1 compaction ratio; therefore, the density figures were adjusted to reflect the uncompacted condition.*

[4] *The average density assumed a mean density figure for 9/26/75 and 10/3/75 of 6.51 lb/ft^3.*

[5] *The average adjusted density assumed a mean density figure for 9/26/75 and 10/3/75 of 3.26 lb/ft^3.*

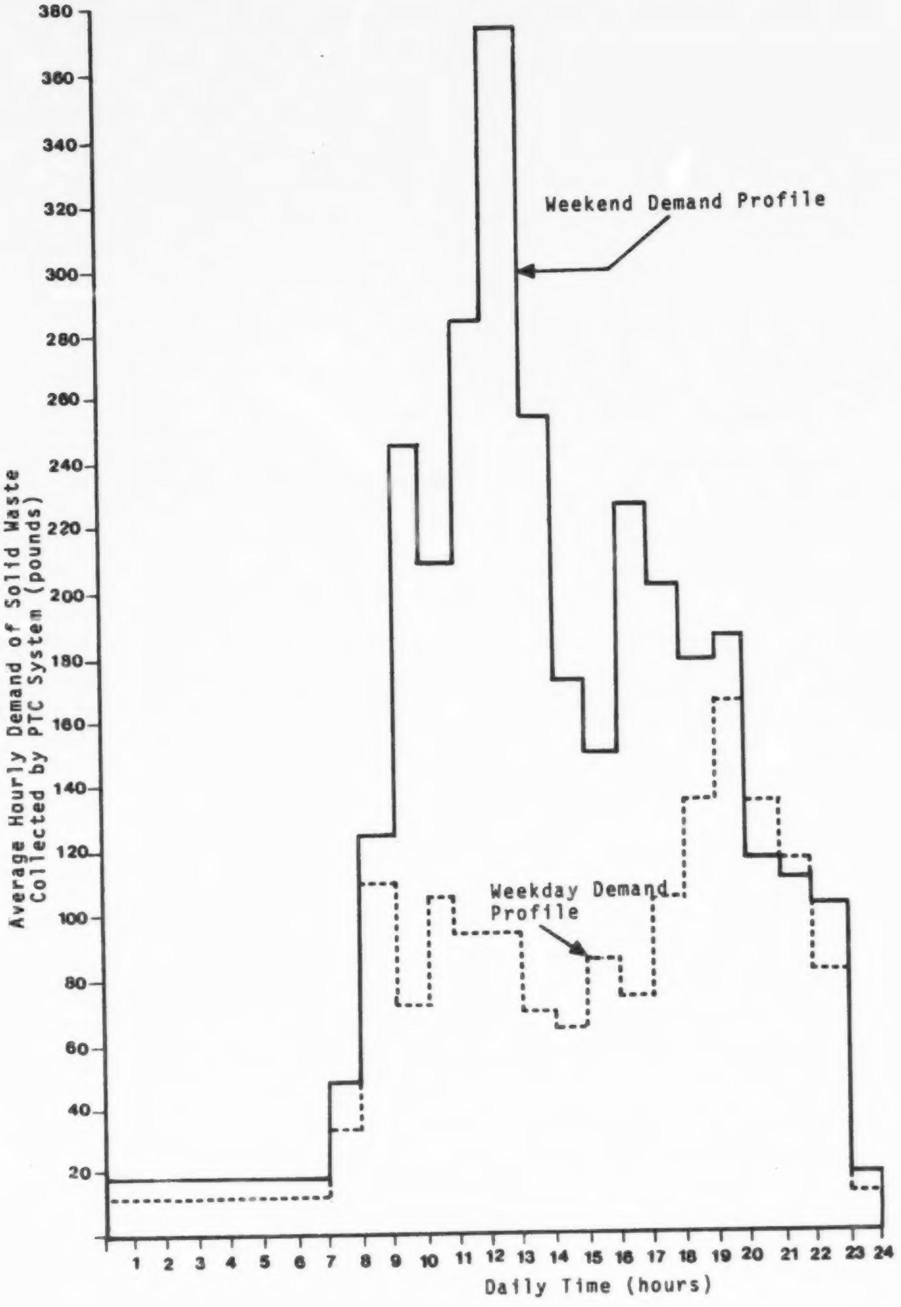


FIGURE 20. Averaged weekend and weekday demand profiles of collected refuse by the PTC system

were measured for every test sample. Some of the test loads, as shown in Figures 21 to 25, were the following:

Low density loads

- loose newspaper
- dry bundled newspaper
- wet bundled newspaper
- plastic trash bags with newspaper
- cardboard boxes
- feather pillows
- loose rags
- loose cans
- loose glass bottles

High density loads

- wood blocks
- plastic trash bag with wet rags
- plastic jars with water
- brick fragments

The densities of the test loads are listed in Table 17. The results for the tests are presented in Table 18.

Main Exhauster Power Consumption Test

The electrical energy used by the main exhausters was calculated by measuring the instantaneous power and elapsed cycle time. The test was conducted on September 3, 1975 and December 15, 1975. The results are reported in Table 19.

Table 17. DENSITY OF TEST LOADS

Description of test load	Density (lb/cu ft)
Balsa wood	8
White pine	23
Fir	30
Walnut	39
Maple	47
Bundled newspapers (dry)	25
Bundled newspapers (wet)	46
Wet rags	43
Plastic jar filled with water	62
Brick fragments	about 100

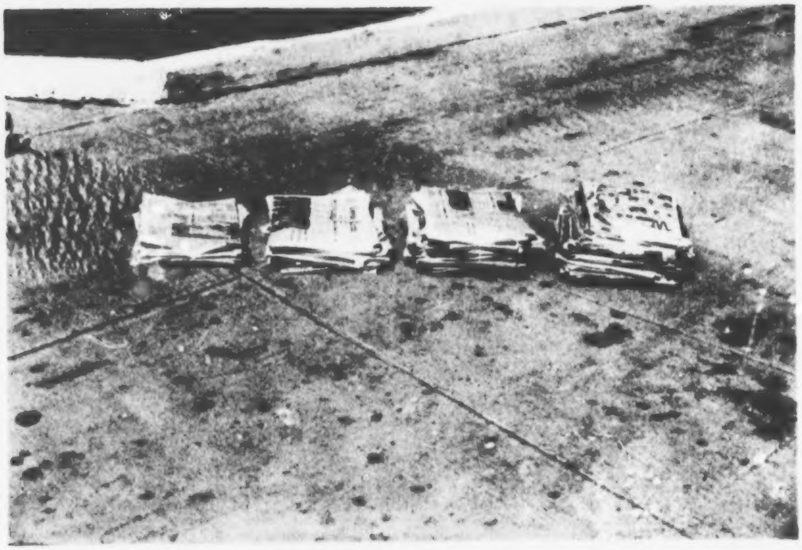


FIGURE 21. Test samples of 5,10,15, and 20 pound bundles of newspaper successfully conveyed by the PTC system during the load capacity test.

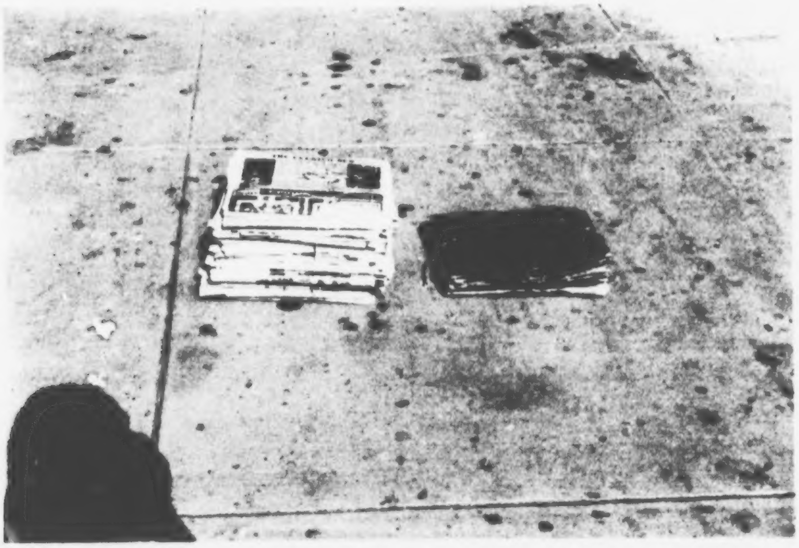


FIGURE 22. Test samples of 30 pound dry and 13.5 pound wet bundles of newspaper successfully transported by the PTC system during the load capacity test.

FIGURE 23. Two feather pillows, cardboard boxes, and plastic bags filled with loose newspaper successfully transported by the system during the load capacity test.

FIGURE 24. Test samples of rags, cans, wood blocks, and glass bottles successfully collected by the PTC system during the load capacity test.

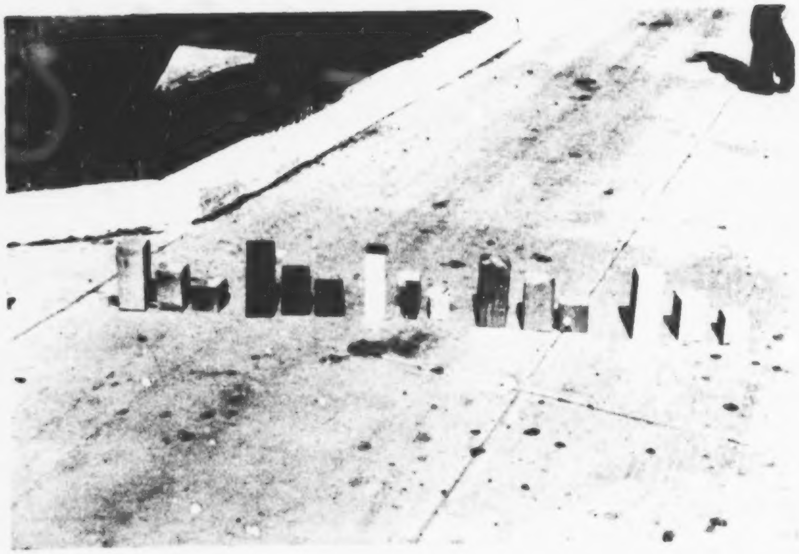


FIGURE 25. Wood Blocks used to simulate high density loads during the load capacity tests. The kinds of wood are balsa, white pine, fir, walnut, and maple. The sizes range from 1" x 3" x 6" to 3" x 3" x 8".

Optimal Schedule Test

The optimal schedule test was conducted from October 31, 1975 to December 17, 1975 to observe the system performance during the operation of a reduced number of schedule cycles. The PTC system was scheduled to operate an average of 18 cycles per day. If the PTC system were able to perform satisfactory with a fewer number of cycles, many benefits may be realized. These benefits include lower operating costs and prolonged component life.

Table 18. TRANSPORT VELOCITY OF TEST LOADS THROUGH THE PTC SYSTEM

Description of Test Load	Elapsed Time from DV-3 to Hopper	Velocity	Velocity
1. Loose crumpled newspapers (5 lb)	10.5-13.5 sec	48.9-62.9 fps	32.6-42.8 mph
2. Crumpled newspapers in plastic bags (5 lb)	10.9	60.6	41.2
3. Cardboard boxes:			
#1 4-1/4"x4-1/4"x9"	12.2	54.1	36.8
#2 7"x7"x9"	11.5	57.4	39
#3 6-1/4"x12"x15"	11.9	55.5	37.7
4. Feather pillows:			
#1	13.2	50	34
#2	12.8	51.5	35.1
5. Loose rags (50 lb)	12.7-16.7	39.5-52.0	26.9-35.4
6. Loose cans (2 ft^3)	11.9-13.9	47.5-55.5	32.3-37.8
7. Loose glass bottles:			
#1 25 lb	17.6-27.6	23.9-37.5	16.3-25.5
#2 18 lb	14.6-26.6	24.8-45.2	16.9-30.7
8. Wooden blocks:			
balsa (3"x3"x3")	13.7	48.23	32.8
balsa (1"x3"x6")	12.4	53.22	36.2
balsa (2"x3"x6")	11.6	56.91	38.7
white pine (3"x3"x3")	16.9	39.15	26.6
fir (4"x4"x4")	15.7	42.04	28.6
walnut (3"x3"x8")	27.1	24.48	16.6
maple (3"x3"x3")	22.9	28.86	19.6
maple (3"x3"x5")	23.1	28.87	19.4
maple (3"x3"x8")	not transported		
9. Bundled newspapers (dry):			
5 lb	15.5	42.6	29.0
10 lb	15.3	43.1	29.3
15 lb	15.4	42.9	29.2
20 lb	17.3	38.2	26.0
30 lb	14.7	44.9	30.5
10. Bundled newspapers (wet):			
13.5 lb	20.9	31.6	21.5
11. Refuse in plastic bags:			
#1	13.9	47.5	32.3
#2	15.9	41.5	23.2
12. Wet rags in plastic bag (30 lb)	17.9	36.9	25.1
13. Plastic jar filled with water	not transported		
14. Brick fragments	not transported		

Table 19. RESULTS FOR THE MAIN EXHAUSTER POWER TEST

Exhauster Number	Average Cycle Elapsed Time	Average Power Per Cycle		Average Energy Used Per Cycle
	minutes and seconds	kilowatts	horsepower	kilowatt hours
Results for September 3, 1975				
1	4:57	109.53	146.88	9.04
2	4:57	109.69	147.10	9.05
Average	4:57	109.61	146.99	9.05
Results for December 15,1975				
1	5:06	110.47	148.15	9.38
2	4:55	110.23	147.82	9.04
Average	5:00	110.35	147.98	9.21

The test schedules were determined by the results from the load profile test. Every peak recorded in the profile test was considered for a possible time for cycling. There were nine test schedules generated, as presented in Table 20. The daily number of cycles varied from 4 to 24 to demonstrate the system performance for a range in schedules.

The performance of the PTC system was closely observed during each test schedule. It was noticed that many system malfunctions occurred during this period which caused frequent service interruptions. Some of these malfunctions were not related to the cycling schedules, such as:

- Compactor failures,
- Discharge valve blockages, and
- Control problems with discharge valves.

These problems severely prejudiced the test results, but one result is that the PTC system could not perform satisfactory with a schedule of four daily cycles. The system could possibly operate satisfactory with a schedule ranging from seven to nine daily cycles, however, the cycle times must be carefully selected. It was observed that with a daily schedule of nine cycles, refuse would back up in the vertical trash chute at Shelly A beyond the first floor charging station. Nevertheless, the PTC system was capable of collecting the refuse without creating any problems. Finally, with a daily schedule of 24 cycles, the PTC system malfunctioned. Thus, it is apparent that many problems with the system were independent of daily cycle schedules.

Noise Level Measurements

The noise levels attributed to refuse collection activities by the PTC system were compared to ambient levels and to Occupational Safety and Health Administration (OSHA) standards. These OSHA standards are reported in Table 21. The noise levels were measured by a General Radio Company Permissible Sound Level Meter, Type 1565-B. The noise levels for the discharge valve rooms and adjacent public rooms are presented in Table 22. The noise levels for the PTC system components in the CEB and for the pull-on container truck are presented in Table 23. The noise level measurements were conducted on March 24 and 25, 1976.

Table 20. SCHEDULED CYCLE TIMES SELECTED FOR PTC OPERATION DURING OPTIMIZATION TESTS CONDUCTED FROM OCTOBER 31, 1975 TO DECEMBER 17, 1975

Cycle Number	October 31 to November 1	November 1 to November 5	November 5 to November 10	November 10 to November 13	November 13 to November 17	November 17 to November 23	November 23 to November 24	November 24 to November 28	November 28 to December 3	December 3 to December 16	December 16 to December 17
1	7:00 AM	7:00 AM	7:00 AM	7:00 AM	one cycle per hour for 24 hours per day	7:00 AM	8:00 AM	8:00 AM	8:00 AM	8:00 AM	8:00 AM
2	12:00 Noon	10:00	10:00	9:00		8:00	10:00	10:00	9:00	10:00	9:00
3	3:00 PM	12:00 Noon	12:00 Noon	11:00		9:00	12:00 Noon	12:00 Noon	10:00	12:00 Noon	12:00 Noon
4	8:00	2:00 PM	1:30 PM	1:00 PM		10:00	1:00 PM	2:00 PM	11:00	2:00 PM	2:00 PM
5		4:00	4:00	3:00		11:00	2:00	5:00	12:00 Noon	5:00	5:00
6		7:00	6:30	5:00		12:00 Noon	4:00	7:00	1:00 PM	7:00	7:00
7		11:00	10:00	7:00		1:00 PM	5:00	9:00	2:00	9:00	9:00
8				9:00		2:00	6:00		3:00		
9				11:00		3:00	8:00		4:00		
10						4:00	10:00		5:00		
11						5:00			6:00		
12						6:00			7:00		
13						7:00			8:00		
14						8:00			9:00		
15						9:00			10:00		

Table 21. OSHA NOISE LEVEL STANDARDS FOR INDUSTRIAL APPLICATIONS.

Noise Level (dba)[1]	Time Duration (hr)
90	8
92	6
95	4
97	3
100	2
102	1.5
105	1
110	0.5
115	0.25

[1] *Impact noise levels must not exceed 140 db.*

Table 22. AMBIENT AND PTC SYSTEM NOISE LEVELS FOR DISCHARGE VALVE AND ADJACENT PUBLIC ROOMS

	Discharge Valve Rooms		First Floor Charging		
Location	Ambient	System	Ambient	System	Remarks
Shelley A South	83 db	94 db	84 db		Noise level from system was lower than the ambient noise level at the charging station. The noise from the system lasted for 13 seconds per hour.
Shelley A	73 to 80	84 to 92	78 to 80		Noise level from system was lower than the ambient noise level at the charging station. The noise from the system was at 92db for 5 seconds per hour.
Shelley B East	75	90	83	85	
Shelley B West	78				Valve was malfunctioned, and did not operate.
Descon Concordia	65	67 to 95			No excessive noise level was recorded from PTC system inside building or outside. The noise from the system was at 95 db for 13 seconds per hour.
Descon Decks			80 to 90		All noise was external and largely caused by street traffic.
Camci			52	90	The noise from the system was at 90 db for 13 seconds per hour.
Commercial		85			No external noise level due to PTC system inside or external of building.

Table 23. AMBIENT AND PTC SYSTEM NOISE LEVELS FOR MAJOR SYSTEM COMPONENTS

Location	Ambient	System	Remarks
PTC Equipment Room	82 to 85 db	90 db	Ambient noise level increased to 90 db within six inches of vent fan. System noise level increased to 102 db within twelve inches of the main exhausters and to 99 db within twelve inches of the collection hopper. These noise levels were for 6 minutes per hour.
Compactor Room	74 to 84	80 to 85	System noise level within twelve inches of hydraulic pump and motor increased to 93 db, and lasted for 2 minutes per hour.
Pull-on Container Truck			Noise level within ten feet of pull-on container truck was 95 db, and averaged between ten to fifteen minutes for each load.

The test showed that the noise level from the system components was, in some cases, lower than ambient noise levels. Furthermore, the noise levels attributed to the PTC system activities did not exceed OSHA standards, and, in general, were much lower than these standards.

Life Cycle Estimates

The entire PTC system was tested extensively to provide reliable data for preliminary life cycle estimates. The tests, conducted on August 7, 8, and 9, 1974; January 21 to 27, 1976; and January 30, 1976, included initial and post characterization tests in addition to static pressure and velocity profile tests.

The major components for the PTC system were characterized before and after the 18 month monitoring program. The results from these tests showed the amount of wear experienced for several system components and served as a basis to predict the service life of each component. The following components were evaluated:

- Main transport line,
- Discharge valves,
- Collection hopper,
- Dust collector,
- Compactor, and
- Chute charging stations.

Main Transport Line --

Weekly static pressure and velocity profile tests were performed to observe any degradation along the main transport line. The original interior surfaces of the line were very rough, as can be seen in Figure 26. The refuse should erode these inner surfaces as it is carried through the system. As the wall erosion increases, the pressure should gradually decrease. This trend, however, was not observed during the monitoring program and the results for the weekly profile tests for degradation in air pressure and velocity are inconclusive.

Two sections of the main transport line were characterized to determine the overall wear of the entire line. A straight section and a curved section were selected as representative samples. Each section was located in the CEB as shown in Figure 27. The wear

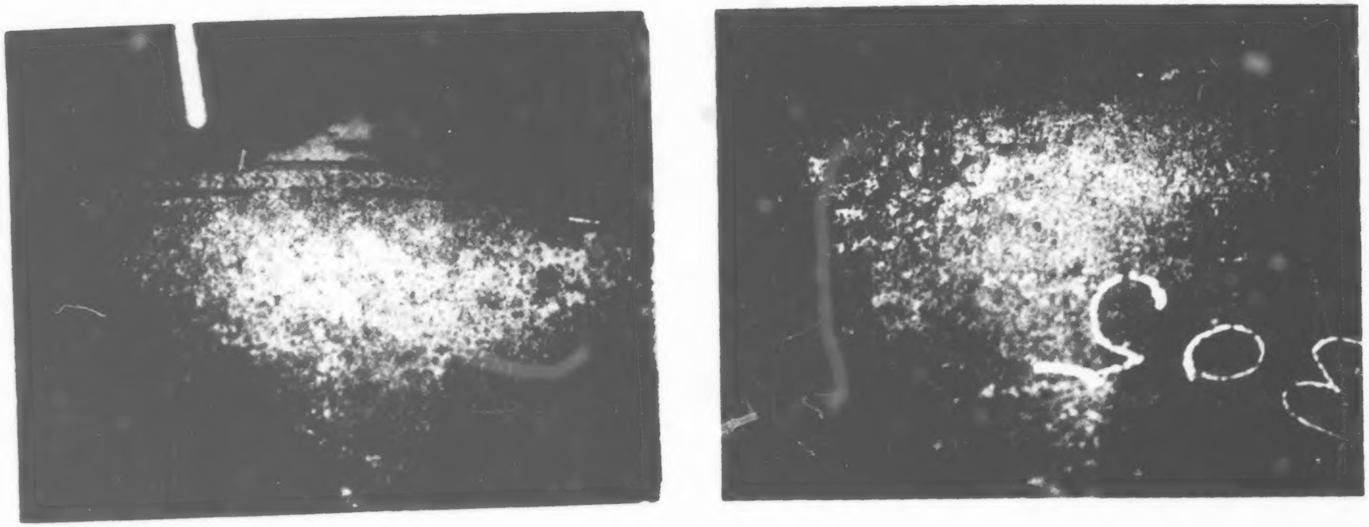


FIGURE 26. Original interior surfaces of the test section of the main transport line.

analysis included consideration in the following areas:

- Test sample weights,
- Interior surfaces, and
- Wall thicknesses.

The weight data indicated that wear was experienced along the main transport line. However, the amount of wear is uncertain. The original test sections were heavily corroded. Formations of rust and scale were observed in the samples, as attested to by Figure 28. These formations would easily erode and prejudice the weight data. A better procedure was considered to weigh the replacement sections, initially, and the test sections after the program. This procedure should provide for more reliable information. The weight data are presented in Table 24.

Table 24. WEIGHT DATA OF THE TEST SECTIONS OF THE MAIN TRANSPORT LINE

	Straight Section	Curved Section
Replacement	658.5 lb	867.0 lb
Sample[1]	633.5	863.0
Difference	25.0	4.0

---

[1] *Weight of sample section after 18 months of service.*

The surfaces of the test samples after 18 months were smoother than the original surfaces. A wear path appeared along the test samples as observed in Figure 29. The interior surfaces were smoother than the original surfaces, as seen in Figure 30.

Surface impressions were made before and after the monitoring program at specified locations in order to observe any wear. These samples were cut so that the surfaces could be viewed by a metallograph and photographed. Two such areas are shown in Figures 31 and 32. In each case, the original surface was rougher than the final surface. Hence, the main transport line did experience wall erosion.

The wall thicknesses of the test sections were measured during the initial and final characterization periods by a Branson Caliper, an ultrasonic device.

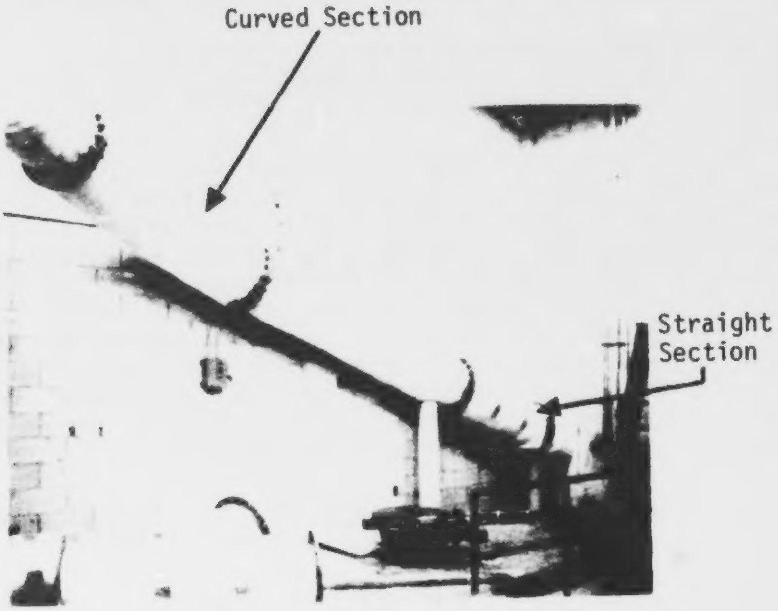

Curved Section
Straight Section

FIGURE 27. A section of the transport line in the CEB showing the two test sections.

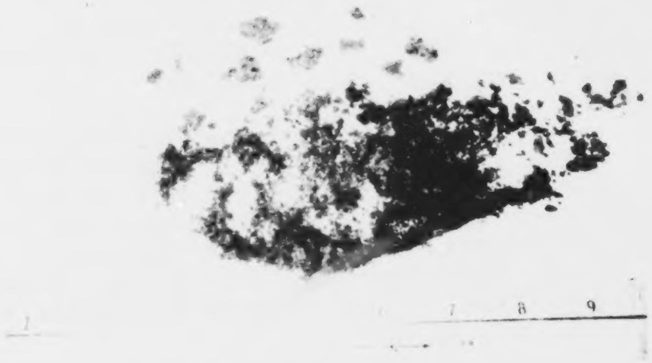


FIGURE 28. A sample of the formations of rust and scale which were removed from the interior test sections of the main transport line during the initial characterization period.

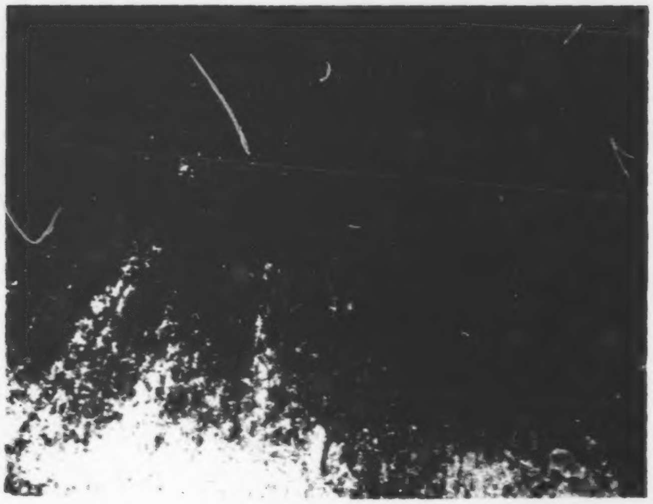


FIGURE 29. Wear path along the straight section of the main transport line before washing.

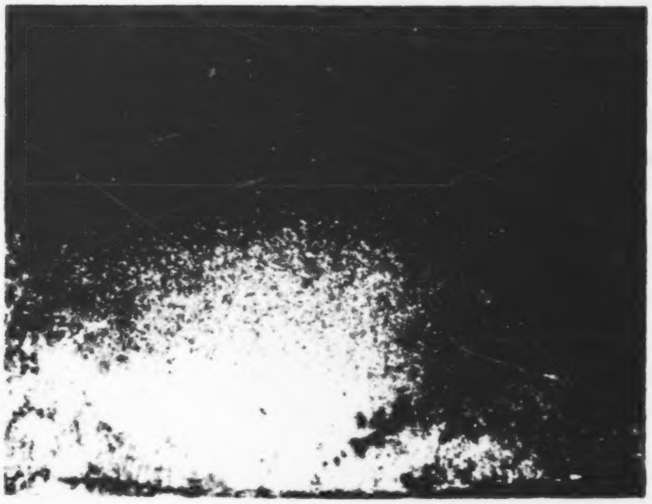


FIGURE 30. Wear path along the straight section of the main transport line after washing.

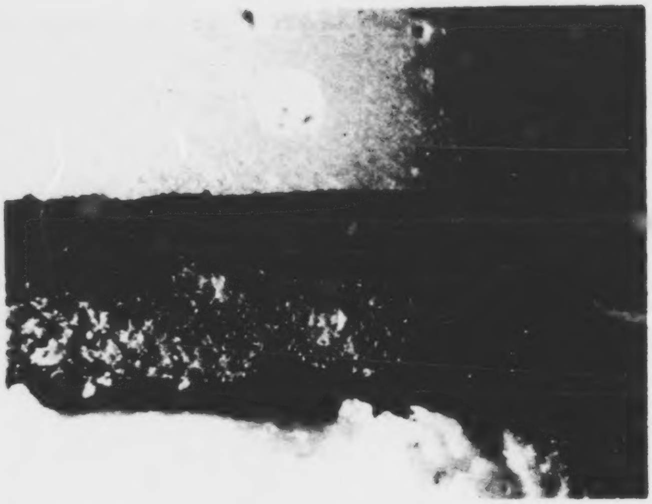


FIGURE 31. Metallographic view of a cross section of the bottom interior surface for the straight test section. The lower view is the original surface while the upper view is the same area after 18 months of operation. The magnification is at 13.3x.

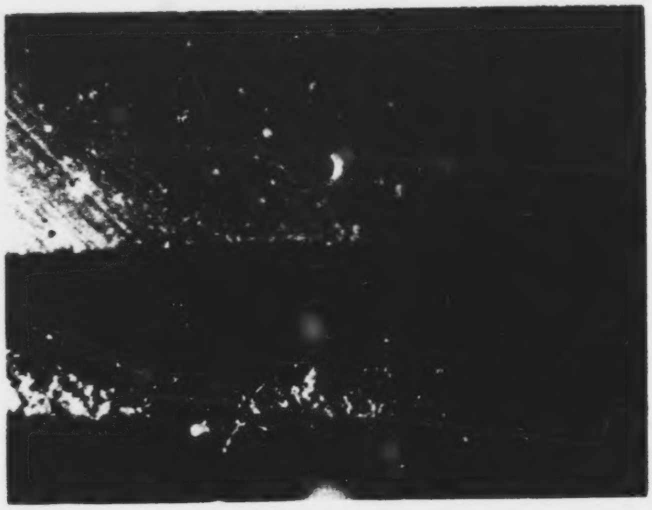


FIGURE 32. Metallographic view of a cross section of one side of the interior surface for the curved test section. The lower view is the original surface, while the upper view is the same area after 18 months of operation. The magnification is at 13.3x.

The differential thickness readings were used to support preliminary life cycle estimates for the entire main transport line. An array of readings taken at six-inch intervals and at fifteen degree rotations was established to provide data. Figure 33 shows the locations for these readings. The results of these measurements appear in Tables 25 and 26 for the straight and curved test sections, respectively.

Discharge Valves --

The discharge valves were analyzed for wear by plate thickness, surface impression, and observation. In particular, the Teflon bearing surfaces and discharge valve plates were investigated.

The Teflon bearing surface, which is one sixteenth of an inch thick, allows the discharge valve plate to slide horizontally. The overall condition of these bearing surfaces after 18 months of operation was very poor. Some sections were heavily scratched and chipped, while other sections were either loose or missing. These conditions are depicted in Figures 34 and 35.

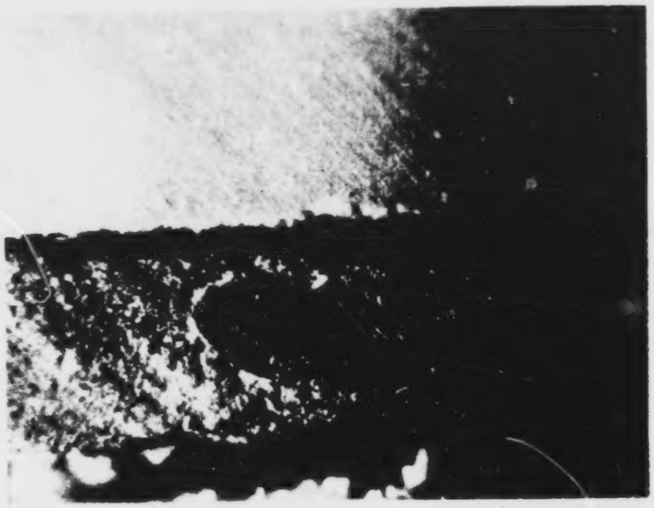


FIGURE 34. Metallograph view of the surface condition of the Teflon seal at the Shelly A discharge valve. The upper view shows the original condition and the lower view shows the condition after 18 months of service. Magnification is at 13.3x.

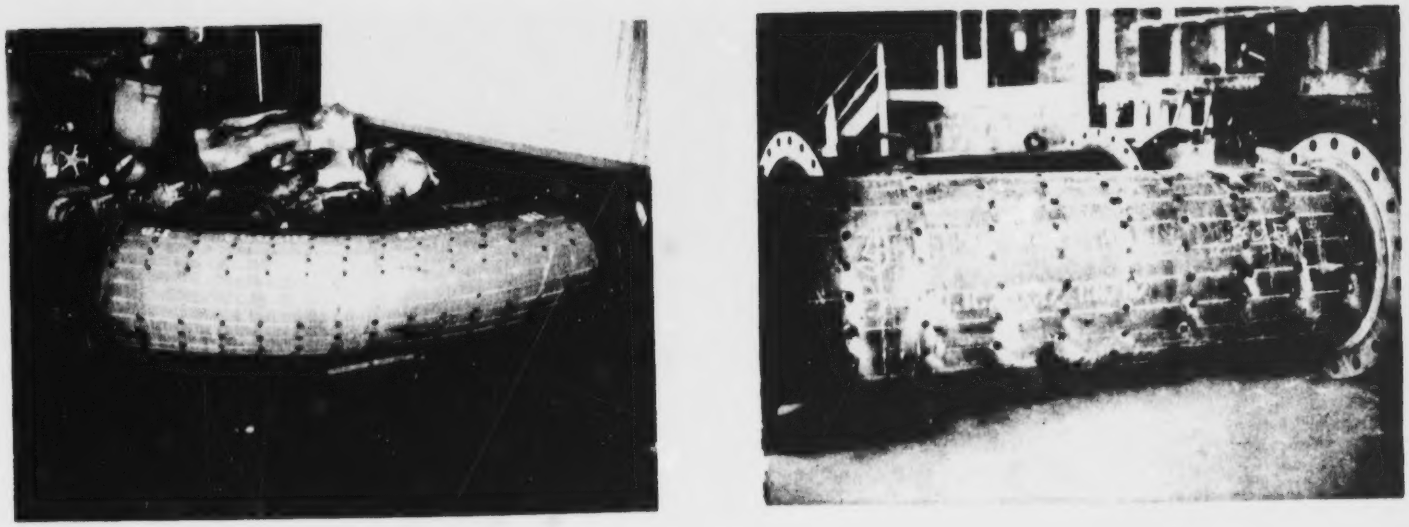
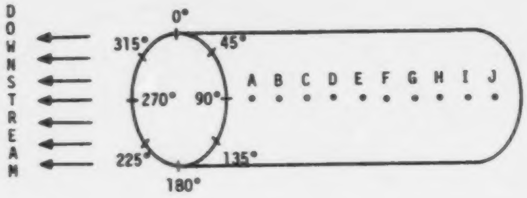


FIGURE 33. Location of wall thickness reading measurements on the straight and curved test sections.

Table 25. WEAR MEASUREMENT RESULTS FOR THE STRAIGHT TEST SECTION OF THE MAIN TRANSPORT LINE

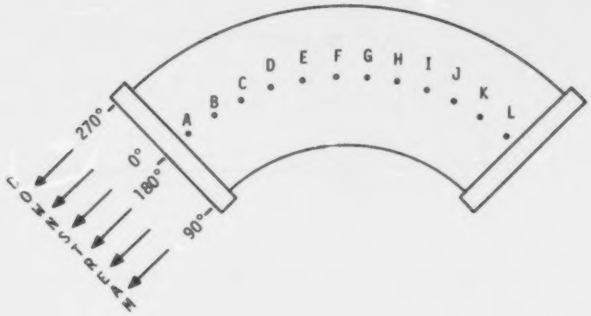


Angle	Column									
	A	B	C	D	E	F	G	H	I	J
0°	0	2	*	5	3	3	3	6	*	0
	0	5	0	7	7	0	3	6	45	40
30°	42	0	5	0	0	0	5	1	5	0
	0	0	0	1	0	0	0	1	46	0
60°	42	0	0	40	0	0	2	0	0	0
	8	0	3	0	0	2	0	0	0	0
90°	53	0	13	0	9	0	5	39	4	3
	42	0	0	44	5	0	6	11	13	51
120°	2	45	0	0	7	4	0	0	4	0
	47	7	4	0	1	1	16	6	4	47
150°	2	5	2	6	9	13	19	10	8	6
	14	3	7	10	9	1	13	51	8	1
180°	51	61	13	41	17	9	15	16	13	0
	4	9	6	8	7	7	9	8	10	10
210°	3	10	0	1	0	3	6	1	1	10
	9	1	2	0	0	3	0	8	0	2
240°	5	0	0	2	2	7	1	0	2	1
	2	1	6	1	10	5	5	11	1	8
270°	5	3	6	1	10	9	8	11	1	8
	3	1	0	10	7	5	0	10	5	10
300°	8	9	14	17	18	18	7	11	16	12
	14	0	10	16	9	5	18	3	7	10
330°	0	0	0	7	0	0	2	9	0	0
	0	0	4	6	9	0	0	3	0	6
360°	0	2	*	5	3	3	3	6	*	10

NOTE: All readings are in thousandths of an inch.

*The hanger of the section was at these positions so that there were no readings made.

Table 26. WEAR MEASUREMENT RESULTS FOR THE CURVED TEST SECTION OF THE MAIN TRANSPORT LINE



Angle	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
0°	6	5	10	10	3	1	0	4	4	3	2	0	1	2	-
15°	6	5	1	45	47	40	52	40	43	1	4	50	0	0	-
30°	3	0	4	41	37	43	0	0	0	0	1	32	0	-	-
45°	6	0	41	45	2	42	4	0	5	0	2	0	1	-	-
60°	0	3	0	40	40	40	42	39	36	0	39	36	0	-	-
75°	1	0	4	0	0	0	43	0	0	0	0	5	0	-	-
90°	0	0	0	0	1	0	26	4	0	0	7	0	1	-	-
105°	0	0	0	0	1	0	0	50	54	44	38	38	0	-	-
120°	0	8	0	2	2	1	2	39	0	5	3	4	0	-	-
135°	5	6	5	8	0	0	8	0	4	1	5	12	3	-	-
150°	12	13	12	11	2	10	11	5	0	5	6	4	1	1	-
165°	5	4	1	3	6	5	1	2	2	5	4	3	2	0	-
180°	8	7	2	10	1	0	0	7	7	0	0	0	0	0	-
195°	5	2	6	13	12	9	17	20	9	7	3	6	6	9	-
210°	4	10	12	17	11	25	20	9	5	2	2	1	0	0	-
225°	7	1	9	13	15	11	10	10	20	7	0	0	3	0	2
240°	9	20	26	29	27	25	16	13	11	47	2	1	0	3	0
255°	22	33	31	32	27	21	23	17	6	7	7	18	18	4	9
270°	17	27	19	18	59	28	50	16	11	9	12	13	9	8	9
285°	19	19	8	10	13	11	13	7	4	0	10	10	2	15	10
300°	4	1	3	0	49	10	9	3	6	3	0	2	1	0	0
315°	9	6	5	7	3	10	8	4	6	3	11	4	43	1	0
330°	0	0	0	0	38	0	0	35	3	0	0	0	0	0	-
345°	1	2	0	43	0	10	5	0	7	0	0	1	0	1	-

NOTE: All readings are in thousandths of an inch.

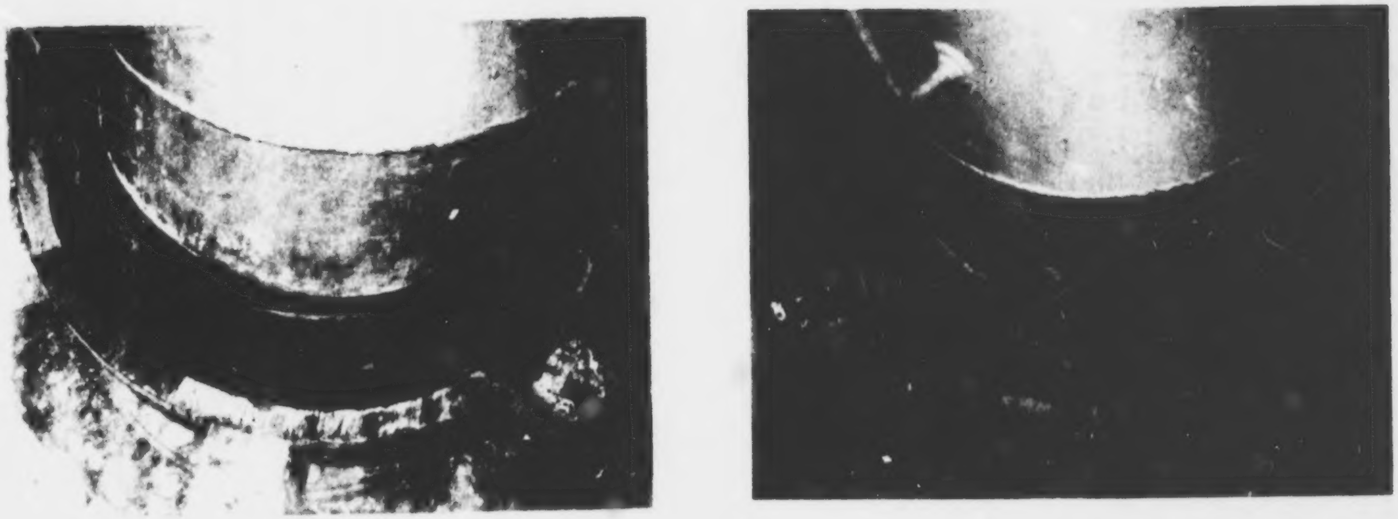


FIGURE 35. Discharge valve at Shelly B East showing the Teflon seal. Its condition is very poor with deep chips, scratches, and missing sections.

The discharge valve plates also showed signs of wear. The top surfaces were heavily dented and scratched as shown in Figures 36 and 37. To find the extent of this wear, surface impressions were made of the valve plates (see Figures 38 and 39). A typical dent of the following dimensions, 0.146 inch long and 0.014 inch deep, is illustrated in Figure 40.

The Branson Caliper was used to measure the thickness of the plates. Figures 41 and 42 identify the locations for measurements. The wear of the discharge valve plates is presented in Figures 43 and 44. These two figures show that the center of each plate experienced the greatest amount of wear.

Collection Hopper --

The collection hopper was investigated for wear. There were stagnant areas near the corners of the collection hopper where refuse stuck to the wall. The refuse accumulated in paste-like layers. Figures 45 and 46 show that these formations were noticeable after one month of operation. By the end of the monitoring program, as illustrated in Figures 47 and 48, these layers were about 1-1/2 to 2 inches thick. However, the majority of the interior surface was very smooth, similar to sand blasted surfaces, as shown in Figure 49.

There was one section directly downstream from the entry line which was dented, and had a one-eighth inch thick crumbly layer of refuse. This is seen in Figure 50. The Branson Caliper was used to measure the wall thickness in this area. The results are reported in Figure 51.

Dust Collector --

The dust collector employed by the PTC system was of the bag house variety. Airborne particulate matter and viable particles were removed from the system air by passing the air through felt filters. The dust and viable particles would be collected on these filter bags and the purified air was returned to the environment. An air shaker apparatus sent bursts of air into these bags to dislodge the accumulated particulate matter. The dust particles fell to a rotary valve which discharged the particles into a drain.

After two months of operation, it was noticed that the rotary valve at the base of the dust collector did not operate properly. Instead of discharging the dust

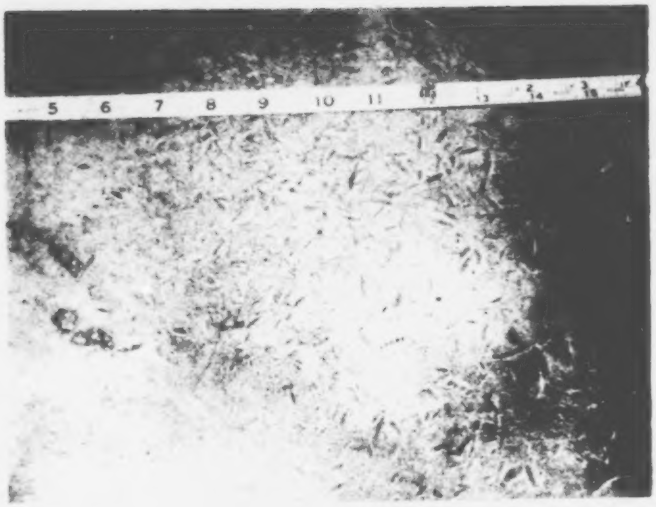


FIGURE 36. Section of the discharge valve plate at Shelley A. The surface is heavily dented.

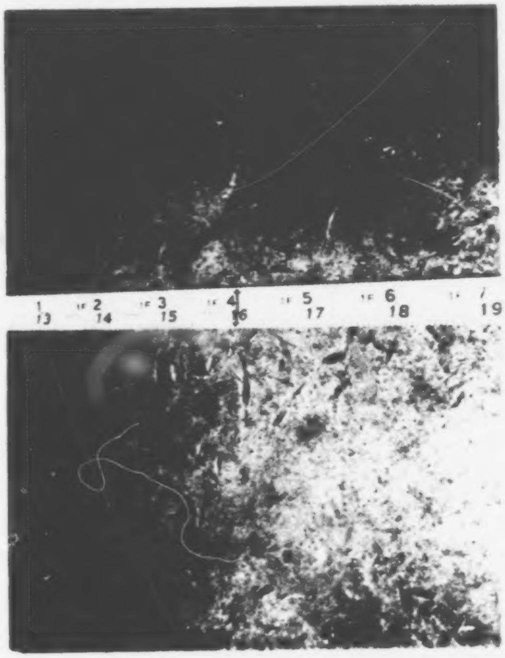

1 2 3 4 5 6 7
13 14 15 16 17 18 19

FIGURE 37. Section of the discharge valve plate at Descon Concordia, showing dented areas.

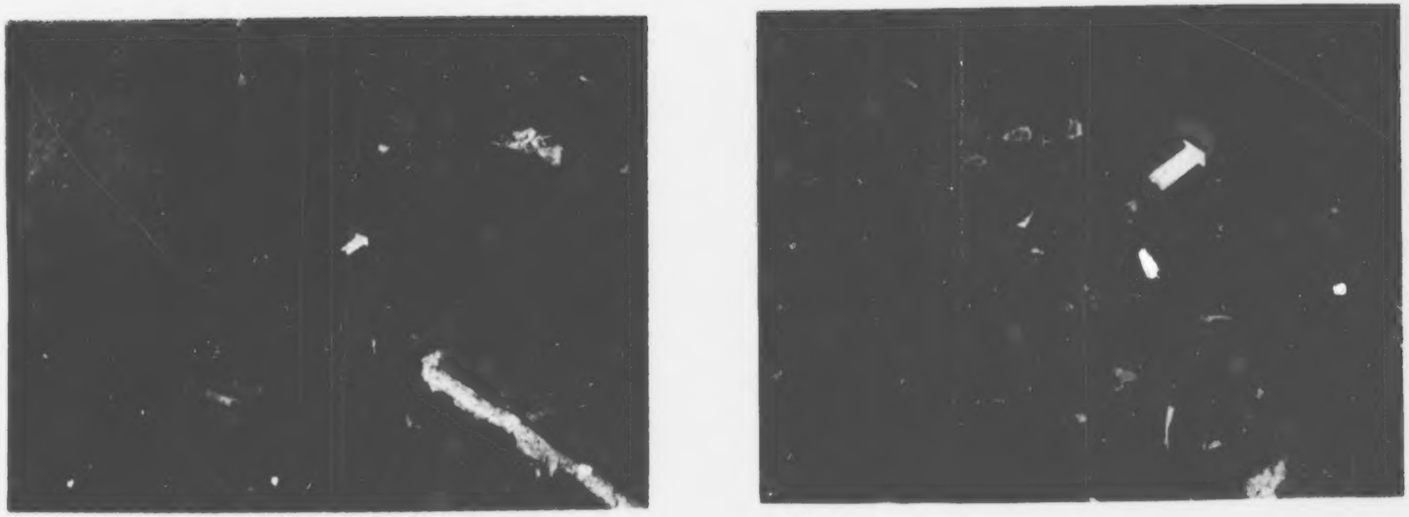


FIGURE 38. Surface impressions of discharge valve plates.

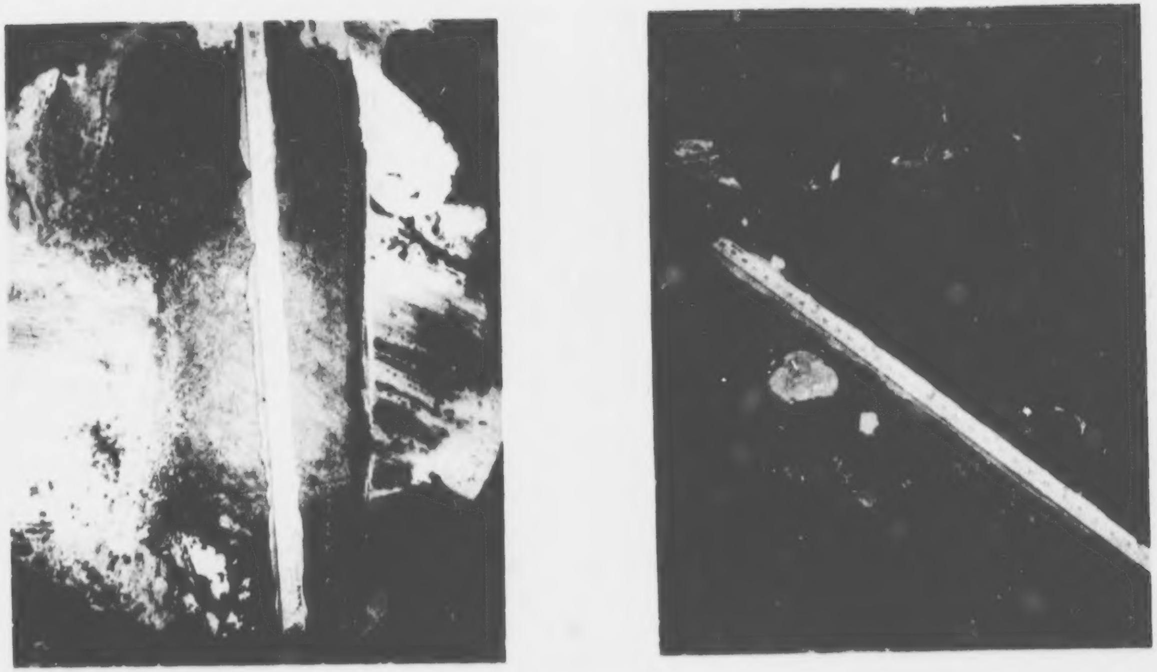


FIGURE 39. Surface impressions of the discharge valve plates at Descon Concordia (left) and Shelley A (right).

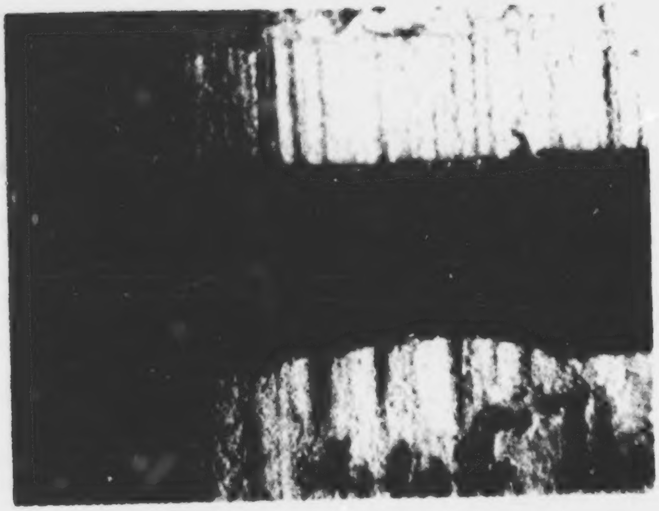


FIGURE 40. Metallographic view of a discharge valve plate replica showing a typical dent. The upper replica shows a portion of an unused plate. The lower replica shows a section of a used plate with a dent of dimensions 0.146 inch long by 0.014-inches deep. Magnification is at 13.3x.

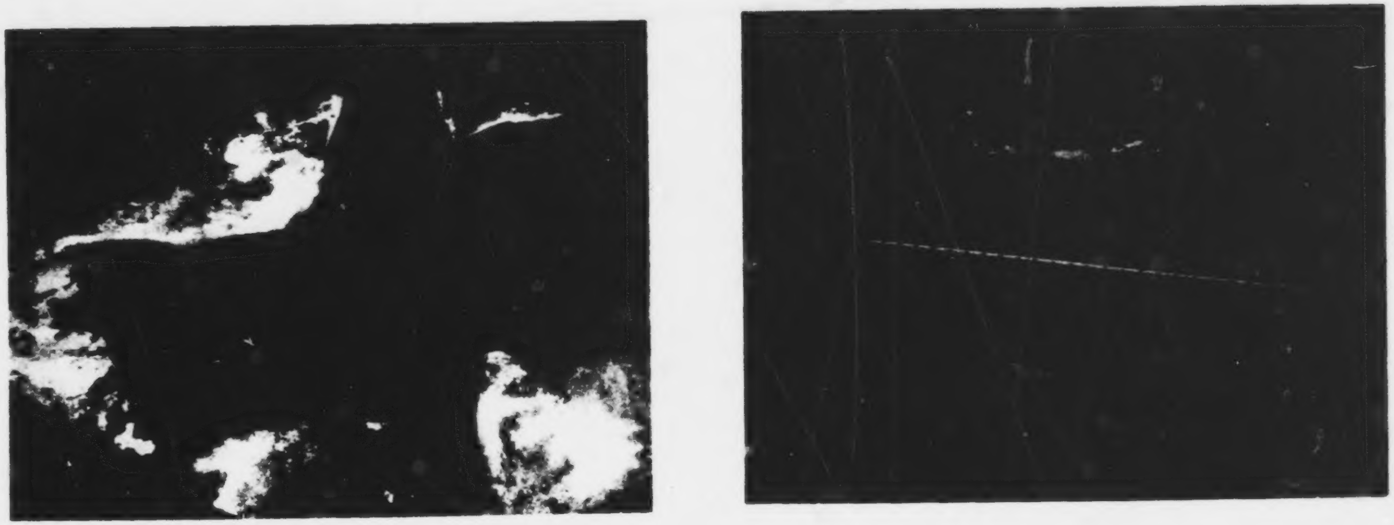


FIGURE 41. Locations on the discharge valve plates used to measure plate thickness. The left view is at Camci, and the right view is at Descon Concordia.

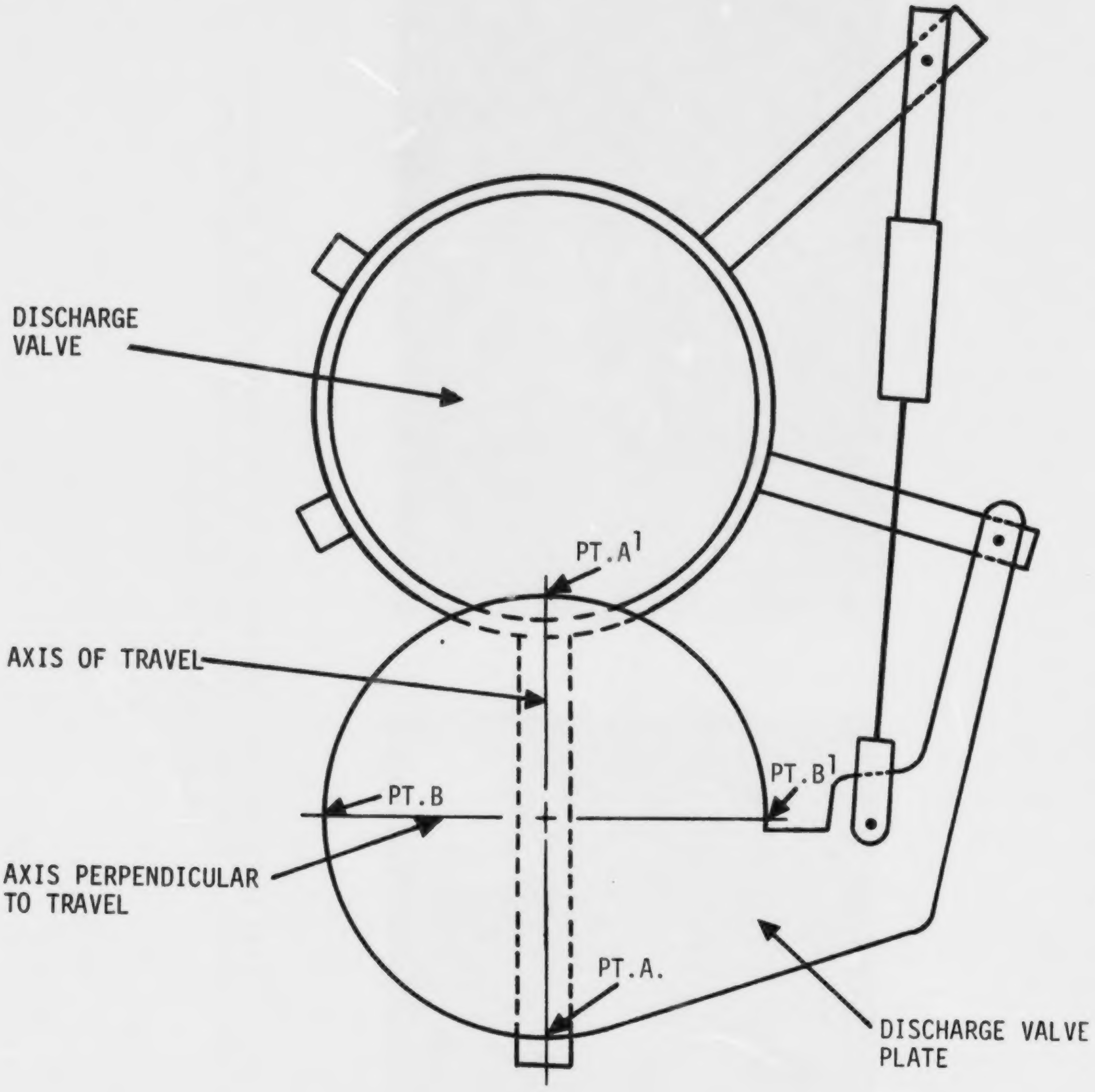

DISCHARGE VALVE
PT.A^1
AXIS OF TRAVEL
PT.B^1
PT.B
AXIS PERPENDICULAR TO TRAVEL
PT.A.
DISCHARGE VALVE PLATE

FIGURE 42. Top view of typical discharge valve showing the locations of the axes used in determining the thickness of the discharge valve plates.

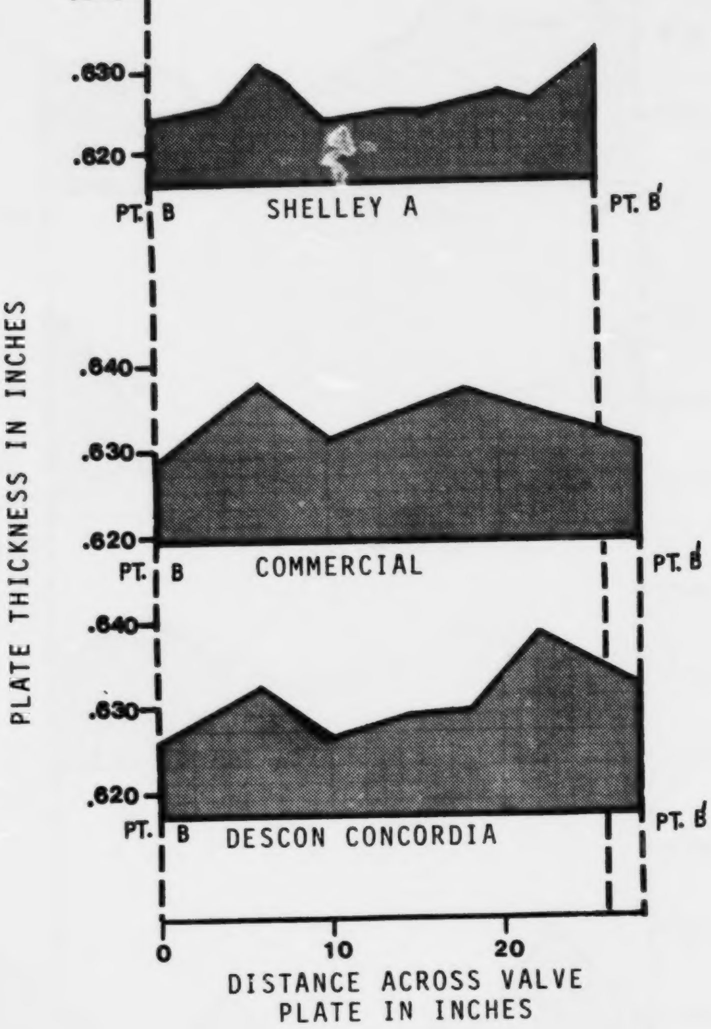


FIGURE 43. Profiles of thicknesses of certain discharge valve plates along the axis perpendicular to travel.

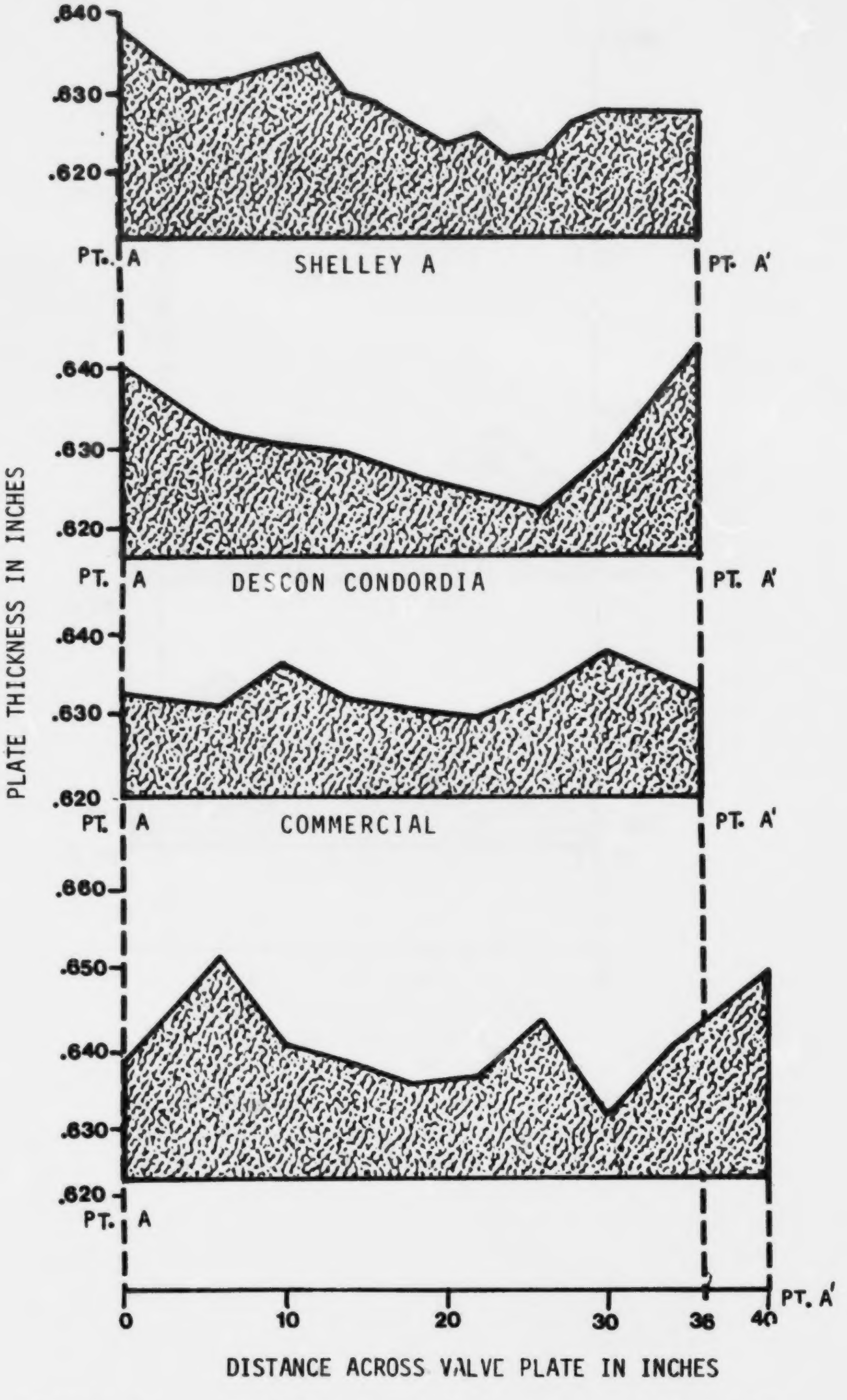


FIGURE 44. Profiles of thicknesses of certain discharge valve plates along the axis of travel.

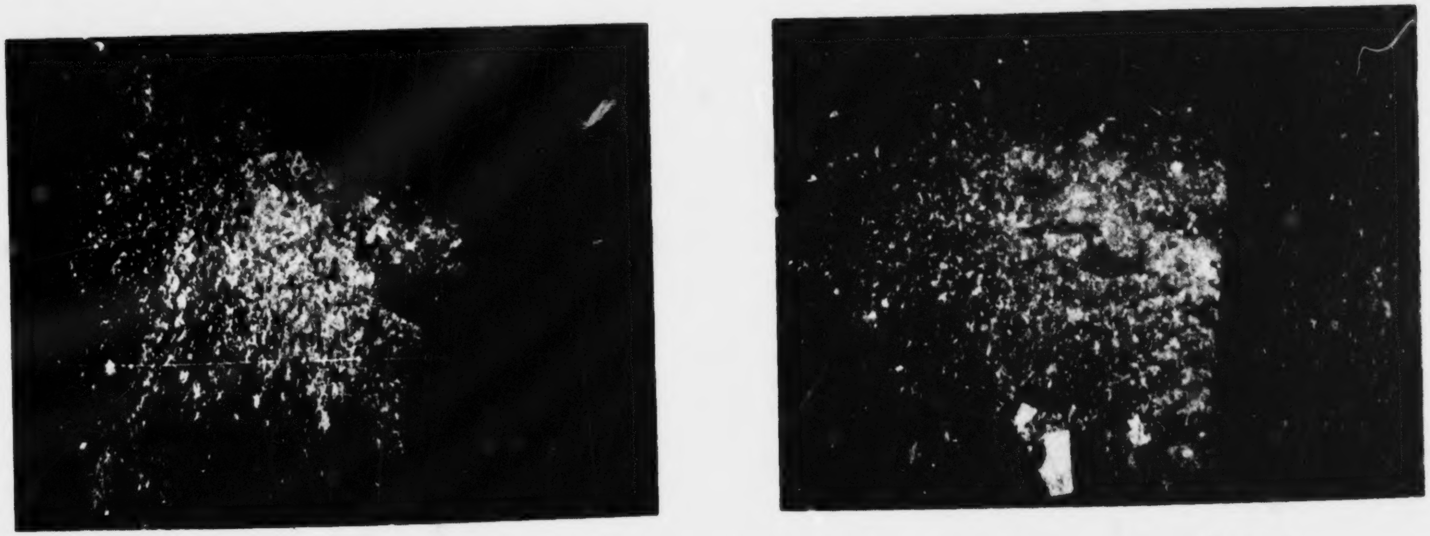


FIGURE 45. Layers of trash and other refuse that have accumulated at the upper corners of the collection hopper after one month of operation. Left side shows the northwest corner and the right side shows the northeast corner of the hopper.

FIGURE 46. Layers of trash and refuse that have stuck to the inside of the collection hopper door after one month of operation.

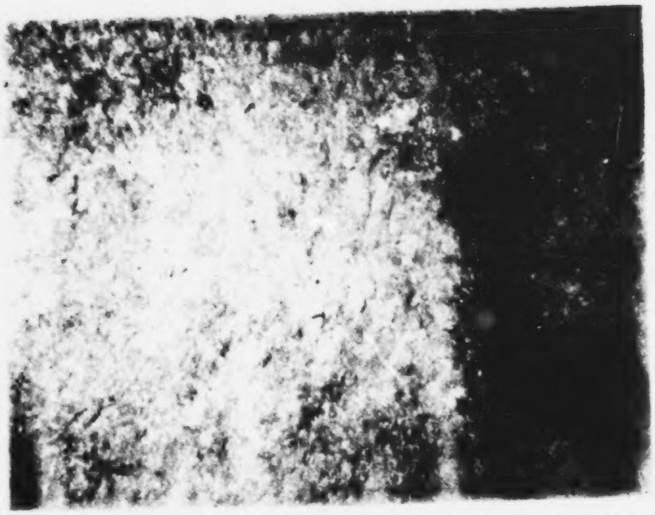


FIGURE 47. Upper southeast corner of the collection hopper showing refuse buildup which is about 1-1/2 inches thick.

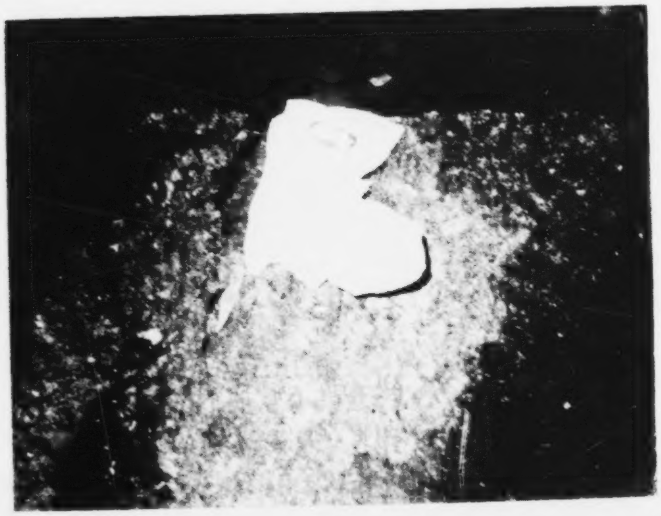
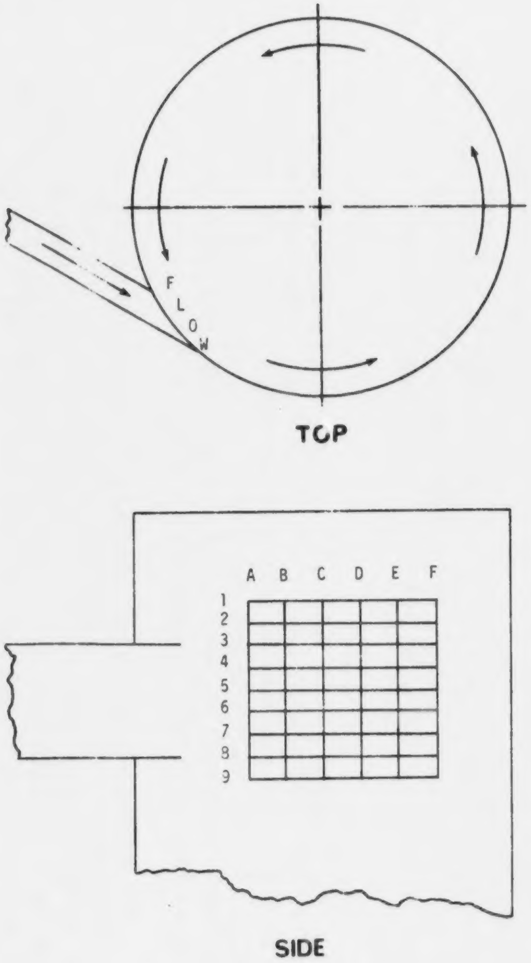


FIGURE 48. Upper northeast corner of the collection hopper. The layer of refuse is about 2 inches thick.

FIGURE 49. Typical wall section of collection hopper. The surface is shiny as though sand blasted and signs of wear are evident.

FIGURE 50. Portion of collection hopper wall about three feet downstream from inlet section. Some denting is apparent and a crumbly layer of refuse, up to 1/8 inch thick, is built-up on the surface.



ROW	COLUMN A	B	C	D	E	F
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	1	0	0	4	9
4	0	1	2	2	4	6
5	0	1	7	4	8	9
6	4	9	10	10	11	8
7	3	9	9	9	9	14
8	0	6	11	13	13	9
9	3	4	4	6	10	9

NOTE: All readings show wear in thousandths of an inch. The columns are spaced in six inch intervals and the rows are spaced in four inch intervals.

FIGURE 51. Wall thickness wear measurements for a test section of the collection hopper.

into a drain, the valve merely collected it and clogged. To alleviate this problem, the rotary valve was removed and a plywood board was placed over the opening at the dust collector base, as seen in Figure 52. The air shaker apparatus was turned off, and the dust particles gathered on the felt filters. Figure 53 shows the filter bags at the end of the monitoring program. Dust particles have coated the bags in layers 1 to 1-1/2 inches deep. The layers are loosely held and any air movement will disturb the dust.

The rotary value was removed and the air shaker turned off in the fall of 1974. Thus, for more than one year of system operation, the dust collector did not operate as designed but the efficiency of the filter was not impaired as shown in the particulate test.

Compactor Equipment --

The compactor unit used in the Jersey City Operation Breakthrough site consisted of a hydraulic refuse compactor assembly and a container handling system. Problems were found to exist in both. The problems associated with the compactor assembly are considered first.

Hydraulic Refuse Compactor Assembly-- Separating the refuse collection hopper from the compactor was a horizontal plate called a hopper gate. This gate operated pneumatically, allowing trash to fall from the collection hopper into the compactor. Here, the trash was compressed by a hydraulic ram into a refuse container.

The hopper gate was set up to operate within a specified time interval. If this time interval was exceeded, the system would malfunction. In the final month of the monitoring program, the gate experienced problems in opening and closing within the designated time which created frequent system malfunctions.

.In order to prevent refuse from scattering out of the compactor unit, neoprene wipers were installed on the hopper gate and on the compactor ram. These wipers were to be adjusted and replaced periodically. During the monitoring program, it was noticed that these periodic checks of the wipers were not performed. As such, the wipers became extremely worn and thus allowed refuse to litter the compacter equipment. An example of the excessive wear on the wipers is illustrated in Figure 54.

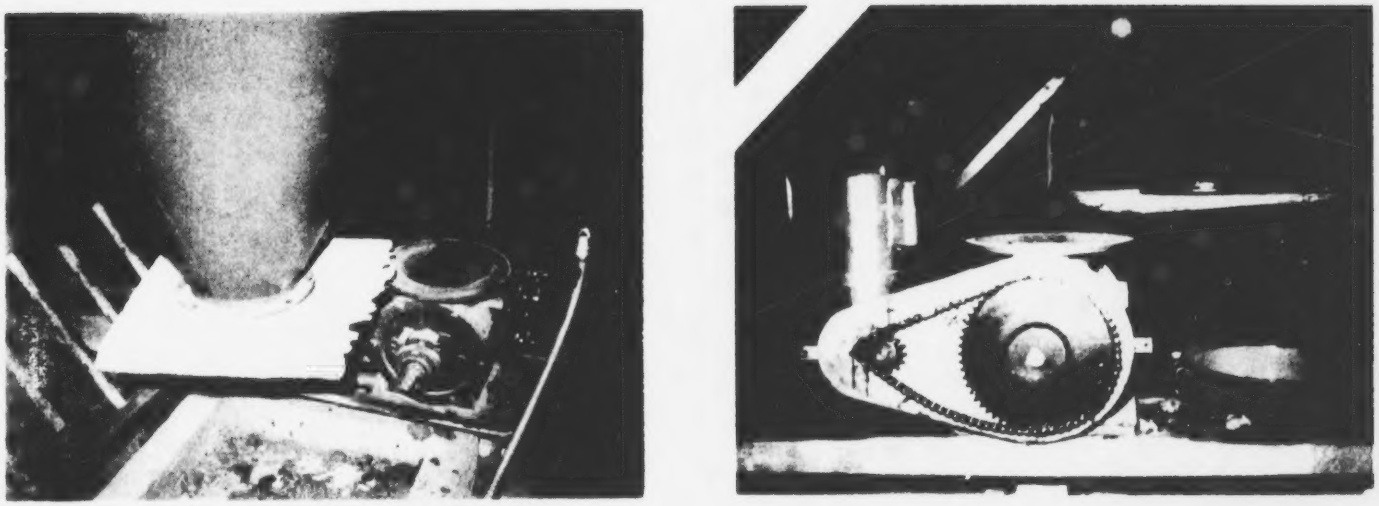


FIGURE 52. Views of the dust collector base and the rotary valve assembly. The rotary valve assembly was removed in the fall 1974.

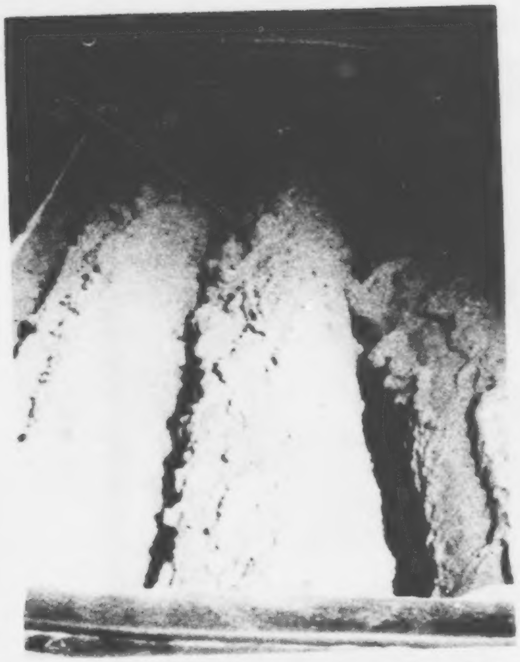


FIGURE 53. Filter bags inside the dust collector after 15 months of operation with air shaker equipment and filter globe valve not working.

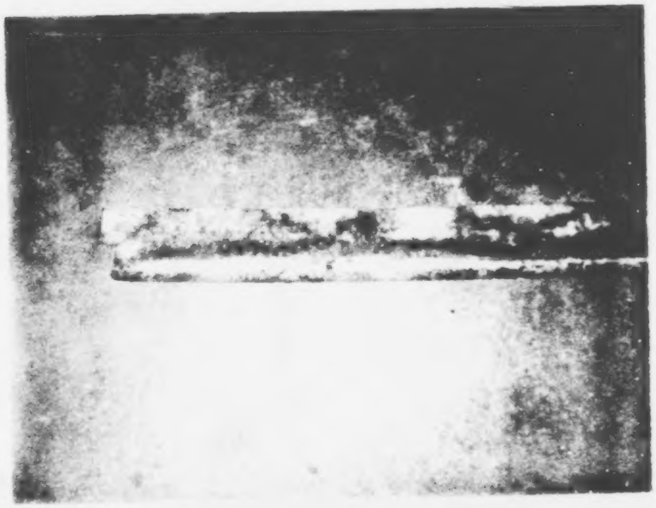


Figure 54. Section of neoprene wiper of the compactor after 18 months of operation. Scratches are about 1/32-inch deep.

The compactor, which compacted refuse into a container, showed signs of wear on all surfaces. Upon close examination, it was found that the wear was composed of fine scratches parallel to the movement of the ram. These scratches are illustrated in Figures 55 and 56.

The top plate of the ram was chosen as a representative sample to determine the extent of the wear for the compactor. A Branson Caliper was used for this task. The test points chosen for measurement are shown in Figure 57. The amount of the wear is depicted in Figure 58.

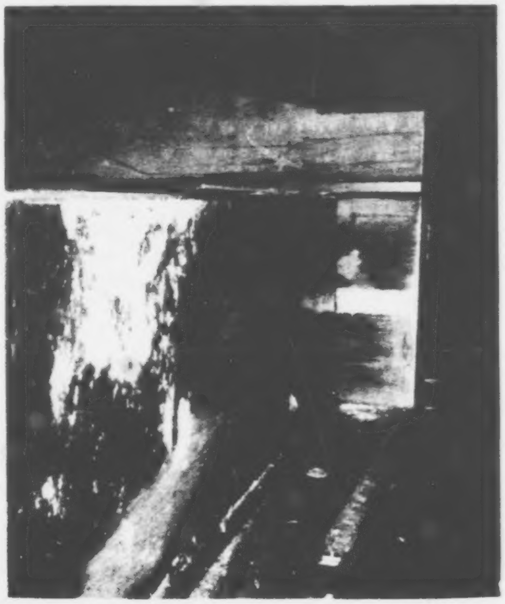


FIGURE 55. Surfaces of compactor and ram showing series of fine parallel scratches.

Another problem with the compactor equipment was found to be the hydraulic fluid. The type of hydraulic fluid used in the compactor ram operated best at a temperature around 70°F. The room that housed the compactor equipment, as stated in the design specifications, was to be maintained at this temperature level. However, because the room was not heated and an exterior door was constantly left open, the required temperature was not met. For these reasons, the hydraulic fluid became sluggish and prevented the compactor ram from operating properly, causing system malfunctions. This was particularly a problem during the winter months.

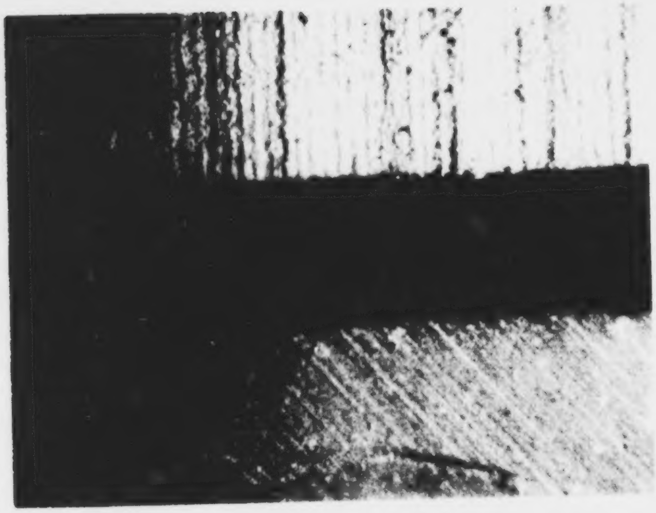


FIGURE 56. Metallographic view of compactor surface replicas magnified at 13.3x. The upper section is the compactor face and the lower section is the compactor ram top.

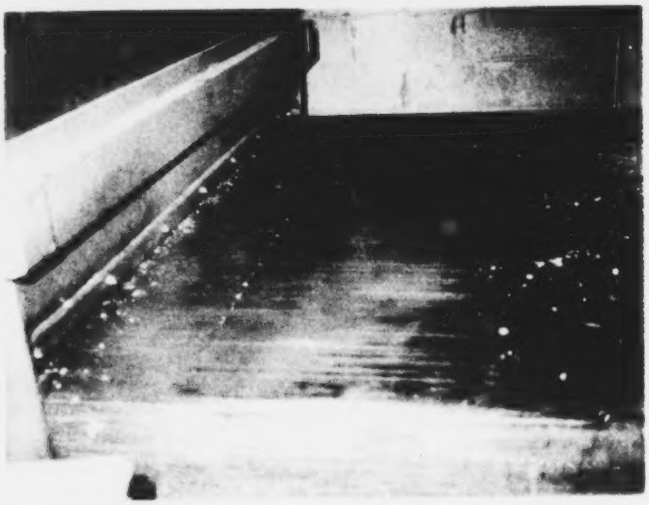
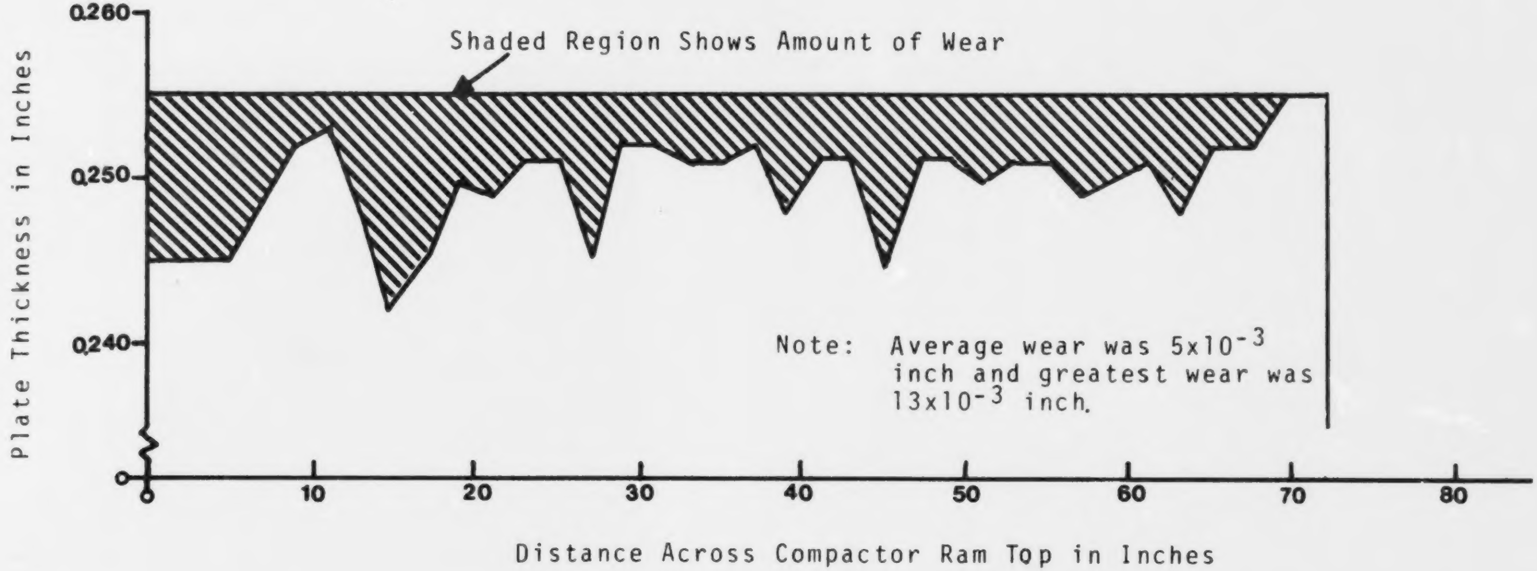


FIGURE 57. Location of points used to measure thickness of compactor top. The row of caliper couplant fluid is to left of center.



Note: Average wear was 5×10^{-3} inch and greatest wear was 13×10^{-3} inch.

FIGURE 58. Cross-sectional wear of compactor ram top.

Container Handling System--The container handling system was composed of a motor control center which operated the system; power and free motion rollers to slide the refuse containers into position at the compactor; hydraulic lift carriages on chain driven trolleys which laterally switched containers to and from the compactor; and various limit switches that showed completed operations. The system was designed to be operated by one man from the motor control center. Basically the system was operated in the following fashion. A full refuse container is moved from the compactor to a pickup area and replaced with an empty container.

Problems were found to exist in the following container handling system components:

- Motor control center,
- Free motion rollers,
- Chain driven power assisted rollers,
- Hydraulic lifts,
- Chain driven drive for the lift carriages,
- Hydraulic line, and
- Limit switches.

Motor Control Center--In the motor control center, (see Figure 59), a problem was encountered with moving

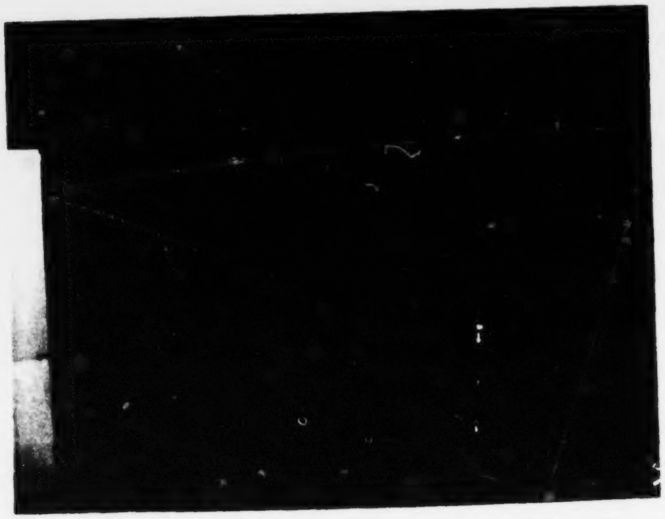


FIGURE 59. The compactor motor control center.

one of two hydraulic lift carriages. (These carriages were used to move the containers laterally from the compactor.) The problem was that a circuit breaker would not remain closed. Thus, the power needed to operate the carriage was not available. To complete the circuit, site personnel closed the contacts of the circuit breaker with a screwdriver.

Free Motion Rollers--Free motion rollers were used to move refuse containers to and from the compactors. The set of rollers closest to the loading dock had problems with the supports for the rollers and the steel frame housing them. Observation showed that the supports for the rollers, called pillar blocks, were crushed, and the entire supporting frame was twisted (see Figures 60 and 61).

Chain Driven Power Assisted Rollers-- Another roller related problem was with the chain driven power assisted rollers. These rollers, which were used in conjunction with the free motion rollers to move refuse containers, were driven by a motor and chain mechanism. The bolts for the sprockets on the rollers would shear. When this occurred, the rollers would not operate, and thus the refuse containers could not be moved.

Hydraulic Lift--The hydraulic lifts were improperly designed in that they were unable to lift a fully loaded refuse container so that it could be moved to the pickup area. Therefore, since the pickup area could not be used, the containers had to be dragged directly from the compactor. This was accomplished by the pull-on container truck when it arrived to pick up the containers for disposal.

Chain Driven Drive for the Lift Carriages--The chain drive, which was built into trenches in the floor, provided the means for lateral movement of the refuse containers. The problem experienced was that trash and litter in the area fell into these trenches and eventually fouled the chains and caused system malfunctions.

Hydraulic Line--There was a problem with the hydraulic line that operated the lift carriages. To protect this line from the chain drive mechanisms, a take-up reel was installed. On one occasion, the hydraulic line became tangled in the take-up reel and was slashed.

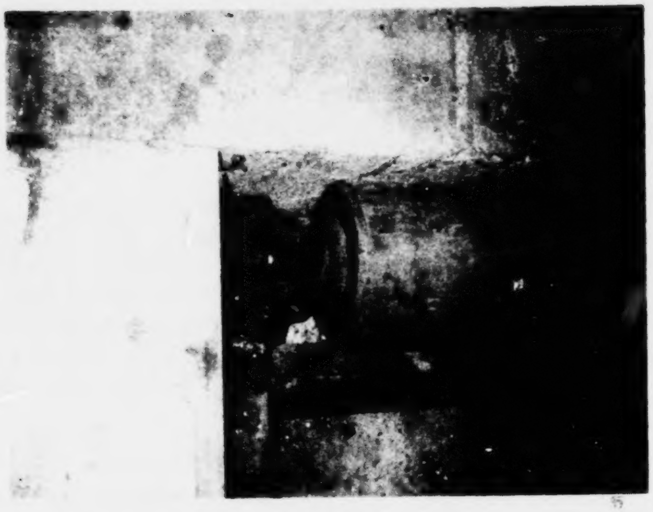


FIGURE 60. One of the shattered pillow blocks used to move containers.

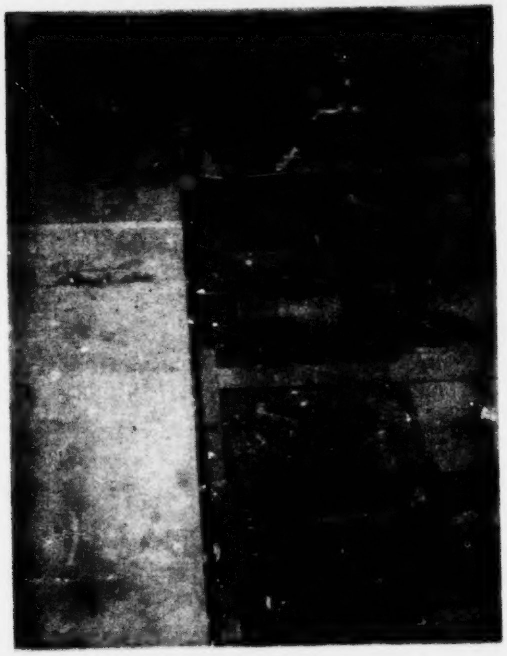


FIGURE 61. View of free motion rollers out of alignment.

Limit Switches--Various limit switches of the container handling system did not operate. During the monitoring period, it was noticed that two limit switches used to show when an empty container was in position at the compactor did not function. At the end of the monitoring period it was observed that these switches had not been repaired.

A problem developed with another limit switch when the original metal doors to the refuse containers were replaced by canvas flaps. When a refuse container was connected to the compactor, the opened metal door would activate a limit switch. This permitted the PTC system to compact refuse automatically. However, the container doors, when replaced by canvas flaps, did not mate with the switches. To override this problem, site personnel permanently fixed the switch so that it always indicated that a container was connected to the compactor. On occasions, refuse was shoved over the floor by the compactor when the container was not in position.

Chute Charging Stations

The fifty-six chute charging stations at the site were investigated to identify types of problems. The results of the investigations are presented in Table 27.

Table 27. DISTRIBUTION OF CHARGING STATION PROBLEMS AFTER 18 MONTHS OF SERVICE

Problem	Quantity	Percent
Rubber safety flap was not installed	36	64
Missing rubber safety flap[1]	7	35
Torn rubber safety flap[1]	4	20
Missing locking mechanism hardware	8	14
Defective chute door return unit	6	11
Chute door failed to close completely	6	11
Chute door scrapes on frame	2	4
Chute door opens into closet door	2	4
Missing chute door handle	2	4

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[1] *These figures are based on 20 chutes, since the other 36 chutes were installed without any flaps.*

ECONOMIC DATA

To determine the actual costs incurred by the PTC system, the period from January 1 to December 31, 1975 was considered. Although the monitoring program ran for 18 months, the first six months of system monitoring, from July to December 1974, were not included because of prolonged downtime periods caused by a multitude of site problems. The areas examined to ascertain the costs of the PTC system included:

- Capital costs,
- Engineering costs,
- Site labor costs,
- Contract labor costs,
- Energy costs, and
- Material costs.

The sources used to gather these economic data were:

- Site and power plant managements,
- Private service contractors,
- Local power utility,
- Equipment manufacturers,
- Department of Housing and Urban Development, and
- Others.

In addition, a record was kept of site labor expenses that were not reported from these sources during the monitoring program.

The actual costs of the PTC system at the Jersey City Operation Breakthrough site are reported in Table 28. A breakdown of the annual labor costs of the system are given in Table 29. The energy usage for the PTC system is about 79,815 kWh per year and is determined in Appendix M. Simply stated, during the monitoring period of January 1 to December 31, 1975, the PTC system collected 248.3 tons of refuse at a cost of $120,021.

It should be noted that all economic data have been converted into terms of October 1975 dollars. This was done because the previous study on the refuse collection systems at the other Operation Breakthrough sites reported costs in these terms (Ref. 2). The common economic base of October 1975 dollars allows the Operation Breakthrough solid waste management systems to be directly compared.

Table 29. ANNUAL LABOR COSTS TO OPERATE THE PTC SYSTEM

	Engineering		Plant Engineer		Contract Labor[3]		Site Labor[4]		Labor Indices	
Month	Actual	Adjusted	Actual	Adjusted	Actual	Adjusted	Actual	Adjusted	Skilled[1]	Common[2]
January			976.50	1,092.67	530.00	562.47	764.25	828.06	1.0712	1.0835
February			361.26	337.23			764.25	825.62	1.0668	1.0803
March			84.15	89.77			764.25	825.62	1.0668	1.0803
April			460.99	490.02			1,113.24	1,198.18	1.0630	1.0763
May			252.47	266.99			764.25	811.56	1.0575	1.0619
June			308.57	318.52	325.00	335.48	917.99	935.06	1.0322	1.0186
July			1,563.88	1,605.15			764.25	774.64	1.0264	1.0136
August	202.32	204.02	743.37	749.63	400.00	410.56	1,181.23	1,185.84	1.0084	1.0039
September	369.40	372.31	210.40	212.06			764.25	766.39	1.0079	1.0028
October			63.12	63.12			1,106.25	1,106.25	1.0000	1.0000
November			539.99	538.81			764.25	763.25	0.9978	0.9991
December			743.38	740.42			764.25	762.26	0.9960	0.9974
Total	571.72	576.33	6,308.08	6,504.39	1,255.00	1,308.51	10,431.95	10,782.73		

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[1] *The skilled labor index converts the actual costs to the adjusted October 1975 costs.*

[2] *The common labor index converts the actual costs to the adjusted October 1975 costs.*

[3] *Contract labor was used to assist site personnel in removing main transport line blockages.*

[4] *The cost data include observed estimated costs.*

TABLE 28. ACTUAL COSTS OF SOLID WASTE MANAGEMENT SYSTEM AT THE JERSEY CITY OPERATION BREAKTHROUGH SITE

Item	Cost[1] Index	Original Installed Costs (Dollars)	Oct. 1975 Adjusted Costs (Dollars)	Carrying[2] Charge	Annual[3] Cost (Dollars/Year)	Percent
CAPITAL COSTS						
Engineering	1.25	$130,116	$162,537	0.079	$12,906	10.8
Discharge Valves	1.25	17,516	21,880	0.079	1,737	1.4
Main Transport Line	1.21	382,956	462,862	0.079	36,751	30.6
Cathodic Protection	1.24	23,696	29,473	0.079	2,340	1.9
Building Chutes and Stations	1.25	18,939	23,658	0.079	1,878	1.6
Compactor	1.00	10,000	10,000	0.079	794	0.7
Compactor Containers and Handling System	1.00	14,000	14,000	0.079	1,112	0.9
Space in CEB[4]	1.23	158,205	194,592	0.079	15,451	12.9
Replacement Parts for PTC Equipment	1.00	1,710	1,710	0.500	855	0.7
Main Exhausters	1.25	30,283	37,829	0.079	3,004	2.5
Dust Collector	1.25	14,921	18,639	0.079	1,480	1.2
Safety Equipment	1.25	16,026	20,019	0.079	1,590	1.3
Vent Fan	1.25	1,105	1,380	0.079	110	0.1
Collection Hopper	1.25	16,758	20,934	0.079	1,662	1.4
Pneumatic Control Lines	1.25	8,842	11,045	0.079	877	0.7
Motor Control Center	1.25	40,893	51,082	0.079	4,056	3.4
Remote Control Panels	1.25	14,368	17,948	0.079	1,425	1.2
Wiring	1.25	14,368	17,948	0.079	1,425	1.2
Electrical System Checkout	1.25	3,316	4,142	0.079	329	0.3
			$1,121,750		$89,782	74.8

OPERATING AND MAINTENANCE COSTS		
Engineering Time	$ 576	0.5
Plant Engineer[5]	6,504	5.4
Contract Labor[6]	1,309	1.1
Plastic Bags	793	0.7
Site Labor[7]	8,593	7.1
Labor Supervision[8]	2,190	1.8
Electricity[9]	2,474	2.1
Hauling and Landfill Fees	7,800	6.5
	$ 30,239	25.2
TOTAL ANNUAL COSTS	$120,021	100.0

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[1] *The cost index is a factor to convert the original installed costs to October 1975 adjusted costs.*

[2] *The carrying charge consists of a 7.5 percent interest rate plus a sinking fund factor for depreciable capital costs.*

[3] *The annual cost for capital equipment is the product of the adjusted costs multiplied by the carrying charge.*

[4] *The space allotted for the PTC equipment in the CEB is about 26 percent of the total space.*

[5] *Plant engineer with 257 hours regular time and 114 hours overtime.*

[6] *Contract labor is used to remove main transport line blockages.*

[7] *2387 man-hours at $3.00 per hour with 20 percent fringes*

[8] *358 man-hours at $5.00 per hour with 20 percent fringes*

[9] *79,815 kWh at 3.1 cents per kWh is supplied by the total energy plant. The local electric utility would charge $3,360 for the same usage.*

The actual costs of the system with regards to the capital costs (Table 28) were determined by converting the original cost dollars to annual cost dollars. This was accomplished by: (1) generating cost index factors in order to convert the original construction costs to October 1975 dollars, and (2) developing carrying charges to adjust the October 1975 dollars to the annual costs.

The cost index factor is a ratio of the construction costs indices for October 1975 to the original construction date indices, as obtained in References 3 to 25. Using this cost index factor, the original construction costs could be converted in October 1975 dollars. Then, these dollars are multiplied by a carrying charge to determine the annual costs of the system.

The carrying charge is the sum of the interest rate and a sinking fund factor for depreciable capital cost, and it is:

$$i + i/[(1 + i)^n - 1]$$

where: i is the interest rate
n is the depreciation period in years

In all cases the depreciation period is considered to be the expected 40-year life of the equipment, and the annual interest rate is established at 7.5 percent.

SECTION V

DATA EVALUATION AND ANALYSIS

The technical and economic data collected during this study of the PTC system (installed and operated at the Jersey City Operation Breakthrough site) were evaluated and analyzed. System performance is investigated with respect to the achievement of design specifications and the assessment of the economy, effectiveness, and feasibility of a PTC system to collect residential refuse. To fulfill these objectives, the following subjects were examined:

- Technical,
- Economic,
- Residential acceptance, and
- Environmental.

TECHNICAL EVALUATION

The data collected during the monitoring program were evaluated to determine the overall system performance and service life for the pneumatic trash collection system. These evaluations were compared to design estimates to observe whether the actual system favorably complied with the design requirements, and to identify those areas where the PTC system did not perform satisfactorily. The specific technical topics considered in these evaluations were as follows:

- Reliability and availability,
- Maintainability,
- Performance, and
- Service life.

Reliability and Availability

The system reliability as observed during the monitoring program was compared to the design conditions. System reliability was defined as the probability that a system would continue to perform for a specified time interval of successful operations. In order to investigate the system reliability, the following topics were considered:

- The overall system availability;
- The probability that the PTC system would continue to collect refuse automatically for a specified number of successful cycles; and
- The evaluation of observed reliability characteristics to recommend design considerations for future applications of PTC systems.

The system reliability as stated in the design specifications declared particular conditions. These conditions are:

- An adequate number of redundant equipment and controls so that a malfunctioned component, or scheduled maintenance for individual components, would not suspend PTC operations;
- All components, parts, and controls must be designed for high reliability;
- A preventive maintenance program;
- Frequency of system malfunctions should not exceed one malfunction per month;
- Repairs should be initiated within 24 hours after a system malfunction;
- Safety controls to prevent component damage, plant failures, personnel injuries, and service interruptions; and
- Signals (visible and audible) at the central control panel to locate malfunctioned components.

Overall System Availability --

The overall system availability was compared to the designed availability. However, before discussing whether the PTC system attained the required level of reliability, several terms must be defined.

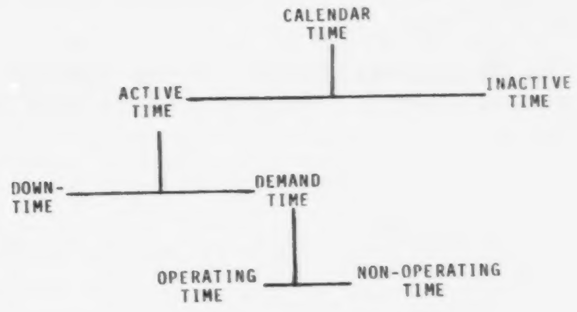
Survival Curve--A graph which shows the probability that a system will remain functional for a specified time interval of successful operations. The mean time between failures (MTBF) as defined by the graph shows the mean time interval that the system will remain in operation before failure.

Repair Curve--A graph which illustrates the probability that a system will be repaired to an operable mode within a specified time interval after a system malfunction. The mean downtime (MDT) describes the time interval within which system has a 50 percent probability of being repaired.

Active Repair Curve--A graph similar to the repair curve except that the time frame includes only the elapsed calendar time required for repairs. The mean active repair time (MART) is the time interval within which system has a 50 percent probability of being repaired once active repair measures are initiated.

Operational Availability (A_0)--A parameter for a system which describes the probability that the system is in an operable mode as measured against active time. The design availability for the PTC was not specifically stated in the design specifications except that there should be no more than one system malfunction per month and that repairs should be initiated within 24 hours after a malfunction.

The reliability data were presented against various time scales, which were calendar time, active time, and scheduled cycles. The calendar time is disaggregated into the following dimensions:



Active Time--The scheduled operating period for each day; for example, automatic operation scheduled to operate every hour between 7:00 A.M. and 10:00 P.M. (16 cycles per day or 15 hours per day).

Demand Time--The operating and non-operating time achieved without downtime in the daily schedule.

Downtime-- The time accrued by failures in the active time schedule.

Operating Time--The time required to complete one cycle of operation.

Non-operating Time--Time between cycles during a scheduled scenario for each day in which the PTC system is ready for operation.

The survival curves for the PTC system are presented in Figures 62 and 63 for calendar and cycle time respectively. The MTBF for calendar time was about 16 hours and the MCBF was 15 cycles.

Maintainability

The observed system maintainability was compared to design expectations. System maintainability was defined as the probability that a failed system could be restored to an operable mode within a specified time interval.

Therefore, the maintainability analysis considered the following topics:

- The repair time required to correct individual component malfunctions;
- The effects of system malfunctions on the collection service;
- The effects and probability of a major system breakdown; and
- The maintainability of the system and recommendations for future PTC system applications.

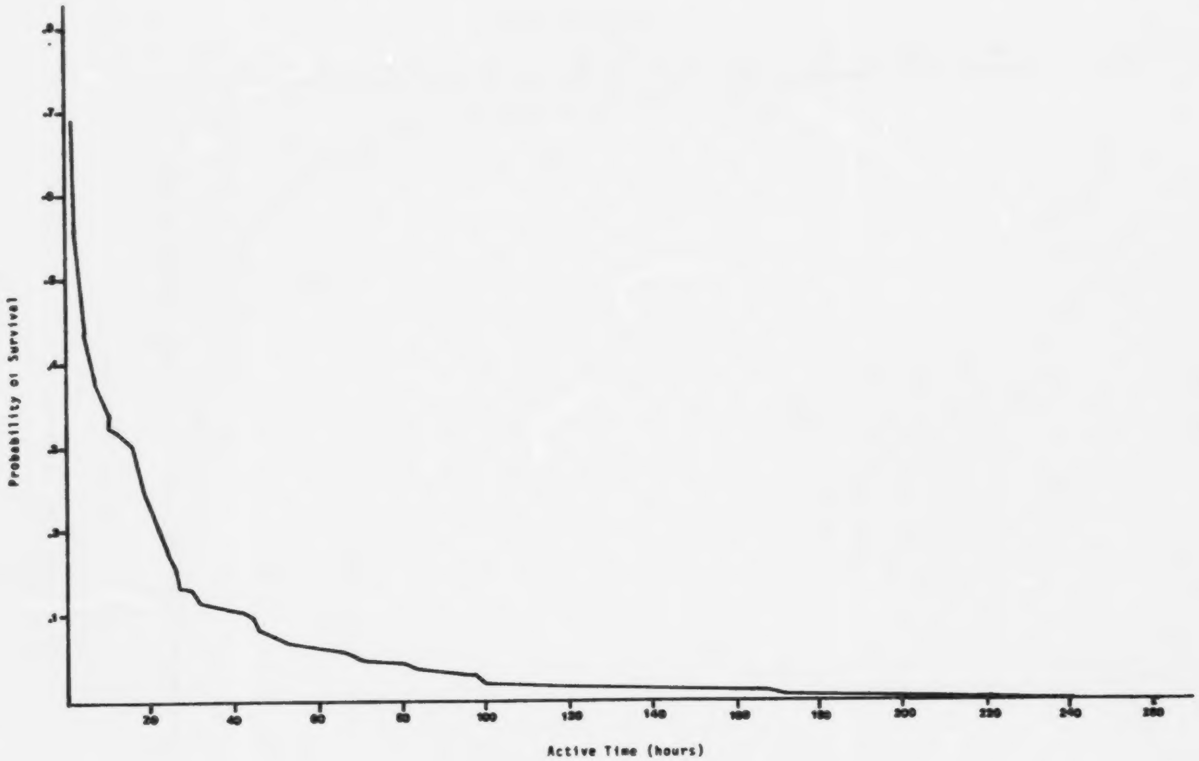


FIGURE 62. PTC system reliability curve: Probability of survival vs. active time.

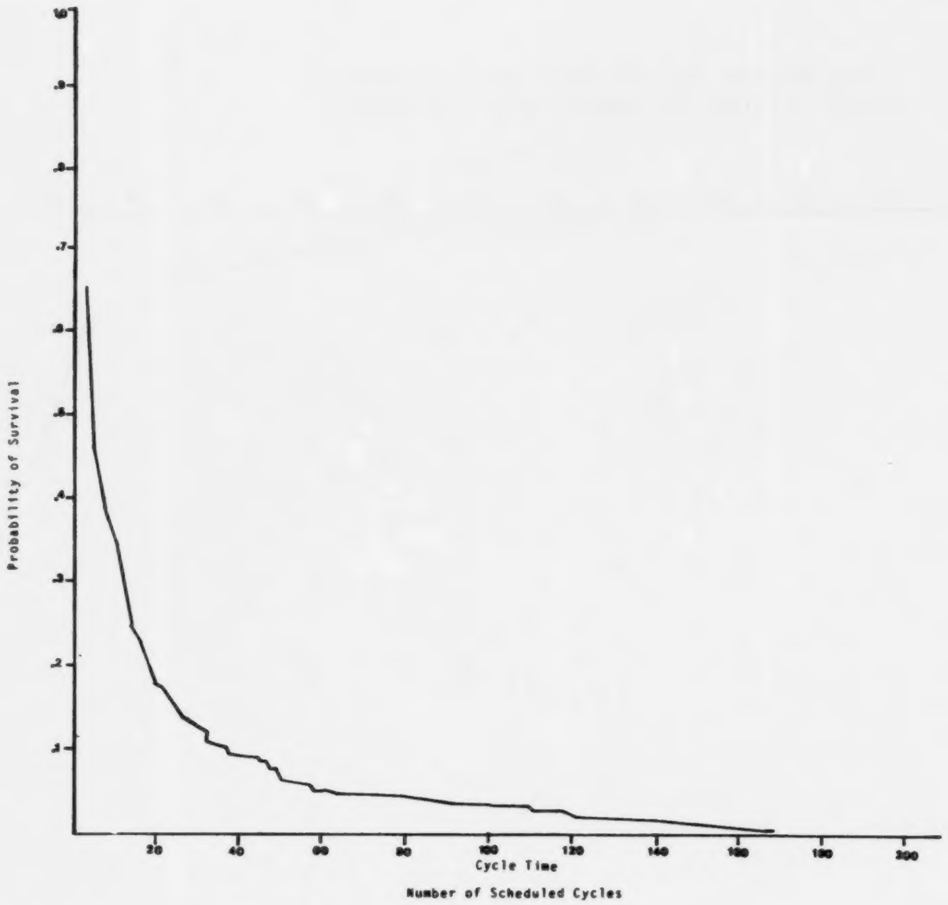


FIGURE 63. PTC system reliability curve: Probability of survival vs. scheduled cycles.

The major components of the system were analyzed with regard to:

- Number of failures,
- Total and mean downtime,
- Total and mean repair time, and
- Total and mean repair time in man-hours.

The maintainability analysis also identified those components which were more critical for successful system operations. This was made by establishing a criticality ranking.

The design specifications listed certain maintenance requirements to reduce repair time and enhance maintainability. These specifications called for the major components to be designed such that all removable parts could be replaced or repaired at the site, and that these repairs would restore the components to the conditions of new equipment wherever practical. Further, mechanical and electrical components should be designed to operate at least 15,000 calendar hours (1.7 years) between major overhaul periods.

The maintainability characteristics for the PTC system are determined by downtime and repair curves. The downtime curves are presented in Figures 64 and 65 for calendar time and missed cycles. The downtime curves in Figure 64 are recorded for calendar and active time frames. The value for the mean downtime (MDT) was 3.4 hours for calendar time. Thus, the mean time to repair the system to an operable mode was about three hours. The mean cycle downtime was three cycles. Therefore, the mean time to repair the system to an operable mode was three cycles. The repair curve for active repair time is shown in Figure 66. The value for the mean active repair time (MART) was assumed to be one-half hour. Thus, the mean time to restore the PTC system to an operable was about 30 minutes after repair efforts were initiated.

A criticality ranking was developed to identify those system components which severely affect the operations of the PTC system. All of the system components were ranked by their achieved availability which is computed by:

$$A_a = \frac{MTBF_c}{MTBF_c + MDT_c}$$

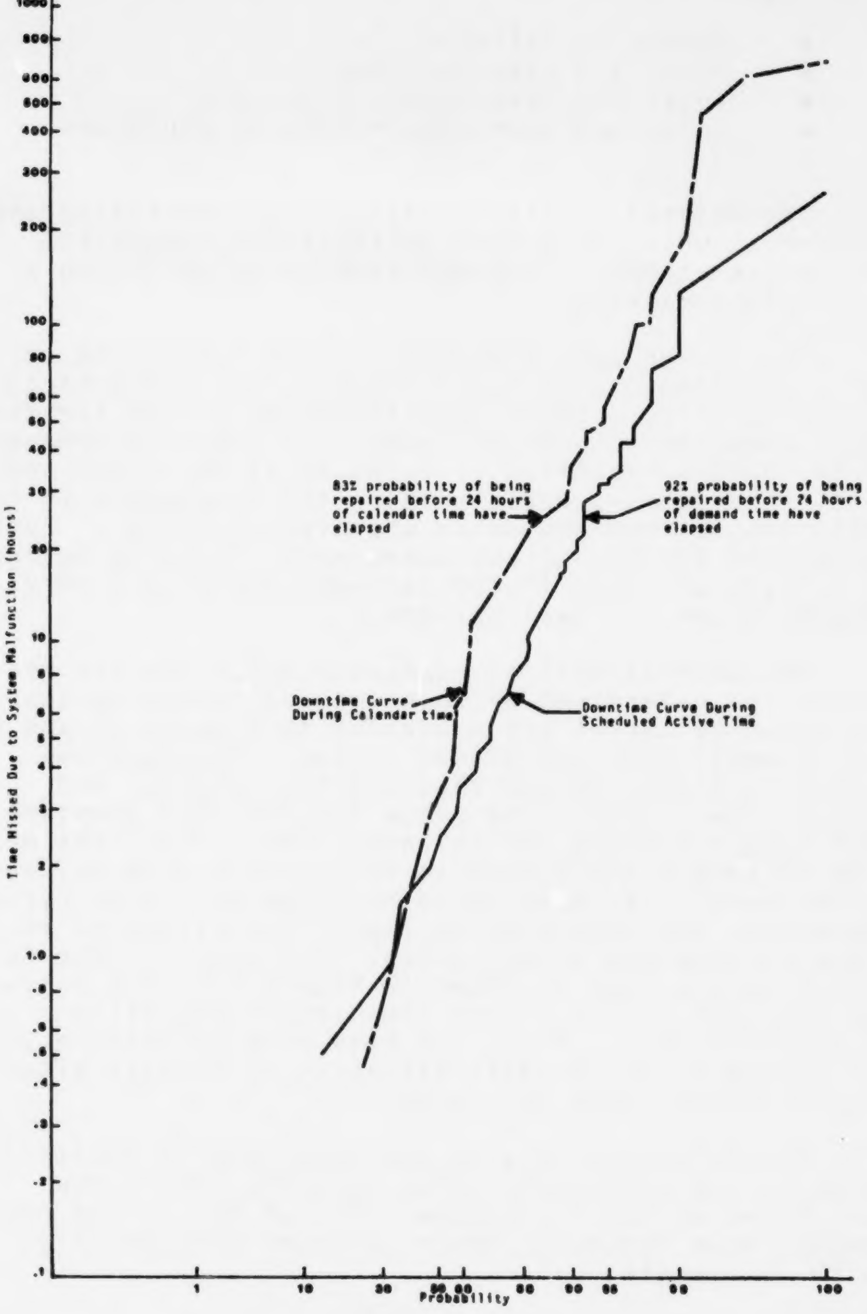


FIGURE 64. PTC system downtime probability curve: Probability that the system would be repaired vs. time.

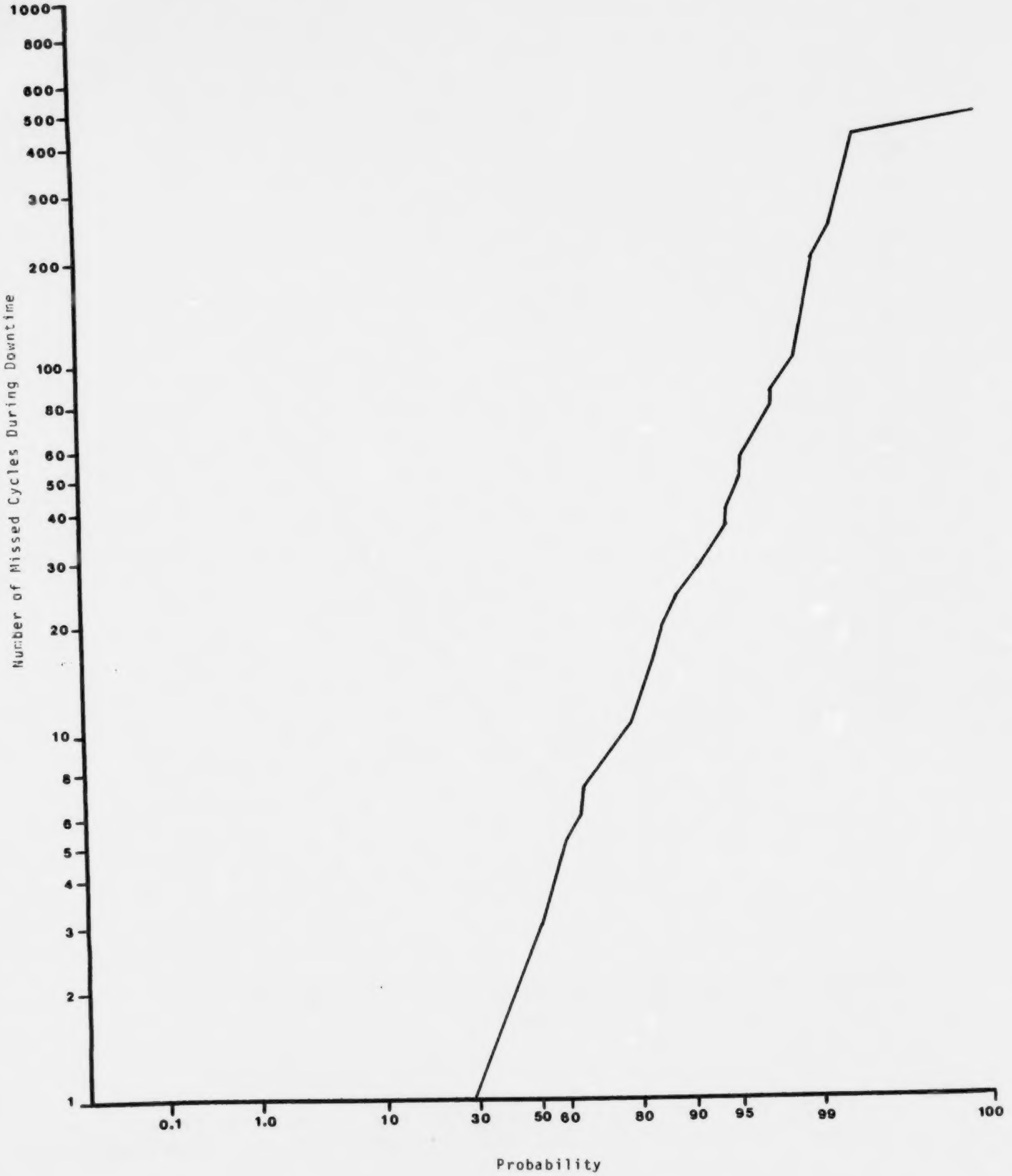


FIGURE 65. PTC system probability of repair curve: Probability that the system would be repaired vs. scheduled cycles.

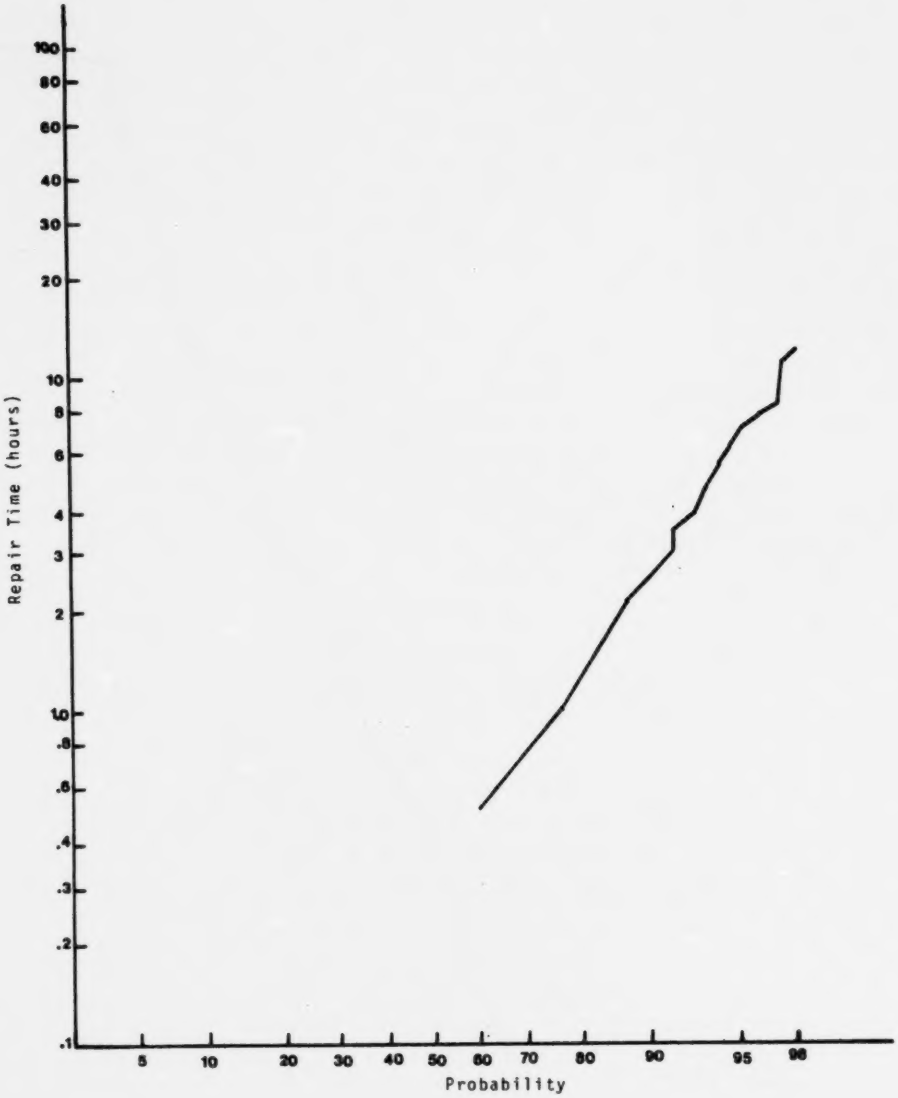


FIGURE 66. PTC system probability of active repair curve: Probability that the system would be repaired vs. repair time once a repair has begun.

where: $MTBF_c$ = mean time between component c failure
MDT_c = mean calendar downtime for component c

This index was used to order the components in a critically ranking. These results, based on total calendar time, are reported in Table 30. An analysis of critical component failures describing the prominent failure modes and design corrective action is given in Table 31. Those system components identified as critical were:

- Main transport line,
- Programmer,
- Discharge valves,
- Control panel,
- Chutes, and
- Compactor.

These six components were decisive for proper PTC system operations. They contributed to 88 percent of all system malfunctions; to 94 percent of the total calendar downtime; and to 89 percent of the total man-hours needed to effect repairs.

The performance for the PTC system was evaluated to discover whether the collection service could be improved. This analysis considered changes for the six critical components and is based on the following assumptions and from Table 30:

- There would be three malfunctions per year in the main transport line due to water infiltration and blockages.

- Malfunctions to the programmer could be reduced by 95 percent to six malfunctions per year. (A majority of the programmer malfunctions were related to a defective power supply which was replaced after 14 months.)

- Many of the problems with discharge valves and chutes were caused by tenants. By educating the tenants as to proper use, these problems could be reduced by 20 percent to 35 discharge valve and 19 chute problems per year.

Table 30. COMPONENT CRITICALITY RANKING BASED ON 18-MONTHS OF CALENDAR TIME

Component	No. of Failures	$MTBF_c$ (hours)	MDT_c (hours)	Mean Man-hours to Repair (man-hours)	Component Availability $\frac{MTBF_c}{MTBF_c \,\&\, MDT_c}$	Ranking
Main transport line	22	597	99.5	21.0	0.86	1
Programmer	116	113	12.2	1.0	0.90	2
Discharge valves	65	202	10.3	2.8	0.95	3
Compactor	38	346	12.6	1.9	0.96	4
Chute[1]	36	365	7.4	3.6	0.98	5
Control panel	3	4380	77.8	17.3	0.98	6
Block valves	9	1460	6.6	3.5	0.99	
Hopper screen	6	2190	1.8	0.6	0.99	
Vent fan	6	2190	9.9	4.5	0.99	
Air inlet valves	4	3285	2.5	0.9	0.99	
Cycle interrupt[2]	4	3285	31.0	2.6	0.99	
Main exhausters	4	3285	18.9	1.9	0.99	
Auxiliary bypass valves	2	6570	4.3	10.8	0.99	
Collection hopper valve	2	6570	1.0	0.8	0.99	

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[1] *Blockages periodically occurring in vertical trash chutes.*

[2] *Cycle interrupts of unknown cause.*

Table 31. ANALYSIS OF CRITICAL COMPONENT FAILURES

Component	Failure Rates (Failures/Million Cycles)	Failure Modes	Effect of Failure on PTC System	Correction Action
Main Transport Line	2,252	a) Water infiltration b) Blockage by large objects c) Blockage by cleaning blocked chutes, or discharge valves, or large masses of refuse would stop air flow	No collection service by PTC system for an average downtime of 100 hours (4 days), and the repair effort usually included outside contract labor to remove the blockage or water.	a) Improve seals for access plates for main transport line and better construction of vaults b) Educate residents and site personnel c) Exercise greater care during manual collection cycles
Programmer	11,876	a) Faulty power supply	Erratic performance of system until replacement power supply was installed.	a) Install new power supply
Discharge Valve	6,654	a) Jamed open with refuse b) Frozen pneumatic lines c) Shorted diodes d) Broken electrical conduit e) Faulty limit switches f) Controls turned off	A mulfunctioned discharge valve stops all collection activities for an average downtime of 10 hours.	a) Implement longer cycling times for specific valves b) Provide supplemental space heat whenever room temperatures approach freezing c) Replace diodes d) Replace conduit and exercise greater care in housekeeping practices e) Establish periodic inspection of all controls f) Establish periodic inspection of all controls
Control Panel	307	a) Shorted power supply b) Control turned off	No collection service for about 78 hours (3 days).	a) Repair short b) Establish periodic inspection of all controls
Chute	3,686	a) Large objects lodged in chute b) Large masses of newspaper lodged in chute c) Fire in chute and sprinkler system did not activate	No collection service from location, and can create a discharge valve malfunction, also prolonged downtimes can create several chute blockages.	a) Educate residents and site personnel b) Educate residents and site personnel c) Exercise more detailed testing of system to ensure that every component functions properly
Compactor	3,890	a) Low hydraulic oil b) Low room temperatures which caused hydraulic oil to become too thick to flow easily c) Controls turned off d) Container filled to capacity e) Container handling equipment broken i) chains snapped to overhead door so that loaded container could not be moved ii) chains snapped to carriages iii) insufficient hydraulic oil for lifts f) Missing container g) Compactor kept cycling h) Container not connected properly	No compaction at end of cycles and can stop all PTC collection activities. A typical malfunction would last 13 hours.	a) Establish periodic inspection of all equipment b) Provide supplemental space heat whenever room temperatures approach freezing c) Establish periodic inspection of all controls d) Establish periodic inspection of all equipment e) Exercise greater care in operating container handling equipment, repair malfunctioned or broken components, and establish periodic inspection of all controls f) Establish periodic inspection of all equipment g) Exercise more detailed testing of system to ensure that every component functions properly h) Exercise greater care in changing containers

- Compactor problems could be reduced by 50 percent to 13 malfunctions per year if site personnel were more attentive to compactor operations.
- The number of malfunctions for the remaining system components were considered to be constant at two control panel malfunctions per year and at 25 system malfunctions for the other components per year.

The reliability and maintainability of the PTC system was determined from these assumptions and the results are presented in Table 32. The MTBF becomes 85.0 hours. The MDT was found to be 13.9 hours, or the average time to restore the system to an operable mode is about 14 hours after the occurrence of a malfunction. The availability for the "improved" system would be 86 percent, as determined by:

$$A = MTBF/(MTBF + MDT)$$
$$A = 85/(85 + 14)$$
$$A = 0.86$$

The availability for the observed system was previously shown by data to be 54 percent. Therefore, the PTC system with these improvements would exhibit an increase in availability of 32 percent.

Many additional benefits would be realized by the improved performance of the six critical system components. The total number of system malfunctions would be decreased from 211 to 103 malfunctions per year which is a reduction of about 51 percent. Furthermore, the total downtime would be decreased from 3737 hours per year to 1427 hours per year for a reduction of about 62 percent. Similarly, total repair time would be decreased by 46 percent (from 357 to 194 hours per year) and total man-hours for repairs would be reduced by 51 percent (from 750 to 367 man-hours per year). These advantages would benefit in lower downtime costs and in an improved refuse collection service.

Performance

The performance of the PTC system was evaluated to determine the overall effectiveness of the system.

Table 32. ANNUAL RELIABILITY AND MAINTAINABILITY FOR THE PTC SYSTEM USING IMPROVED COMPONENTS

Component	Failures/Year	Downtime in hours		Repair time in hours		Repair time in man-hours	
		Total[2]	Mean[1]	Total[2]	Mean[1]	Total[2]	Mean[1]
Main transport line	3[2]	298.5	99.5	17.7	5.9	63.0	21.0
Programmer	6[2]	73.2	12.2	4.8	0.8	6.0	1.0
Discharge valves	35[2]	360.5	10.3	56.0	1.6	98.0	2.8
Control panel	2[2]	155.6	77.8	34.0	17.0	34.6	17.3
Chutes	19[2]	140.6	7.4	26.6	1.4	68.4	3.6
Compactor	13[2]	163.8	12.6	16.9	1.3	24.7	1.9
All others	25[1]	235.0	9.4	37.5	1.5	72.5	2.9
Total	103	1,427.2	13.9	193.5	1.9	367.2	3.6

---

[1] *These figures were from the observed data for the PTC system.*

[2] *These figures were estimated for the improved system.*

The analysis considered the following areas:

- The ability of the system to comply with design loadings;
- The ability to transport overweight, oversized, and other bulky solid waste;
- The capacity of the system for design loads, actual loads, and operating schedules;
- The ability to safely handle dangerous materials;
- The adaptability of the system to recycle specific classes of solid waste;
- The adequacy of safety equipment including provisions to prevent component and plant failures, personnel injuries, service interruptions and fires; and
- The ability of the system to perform under low ambient temperatures.

System Ability to Comply with Design Loadings --
The ability of the PTC system to collect the design refuse loading was investigated. The design estimate for the refuse loading was about 7200 pounds per day or 1300 tons per year. The site generated only 250 tons per year of refuse, which is about 19 percent of the design capacity. The system was operated about once every hour which was sufficient for the observed site loads. For the PTC system to handle the full design loading of 1300 tons per year, the cycle schedule may have to be adjusted to operate at fifteen or twenty minute intervals. Hence, the system components could handle the design loading.

System Ability to Transport Various Sizes and Weights of Refuse --
The ability of the PTC system to transport overweight, oversized, and other bulky solid waste was studied in the load capacity test and by observing the unusual kinds of refuse transported by the system. The tenants had placed many unusual objects in the PTC system which had been successfully collected. Figures 67 through 70 show some objects that were successfully conveyed by the system. These objects include the

FIGURE 67. Two wood pieces, curtain rods, and wire rack successfully collected by the PTC system.

FIGURE 68. A mechanical adding machine 7.5 inches wide, 11 inches long, and 4 inches high which was successfully transported by the PTC system.

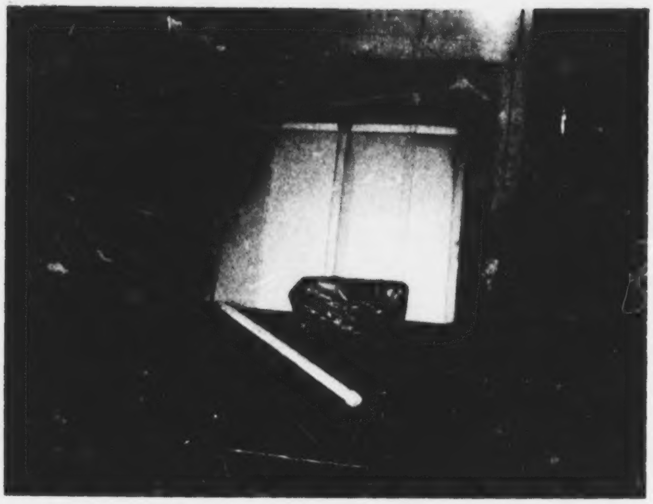

FIGURE 69. One large piece of cardboard, about 3 feet by 4 feet, a shopping basket, a plastic pipe about 3.5 feet long, and a foot weight from a weightlifting set, which were successfully collected by the PTC system.

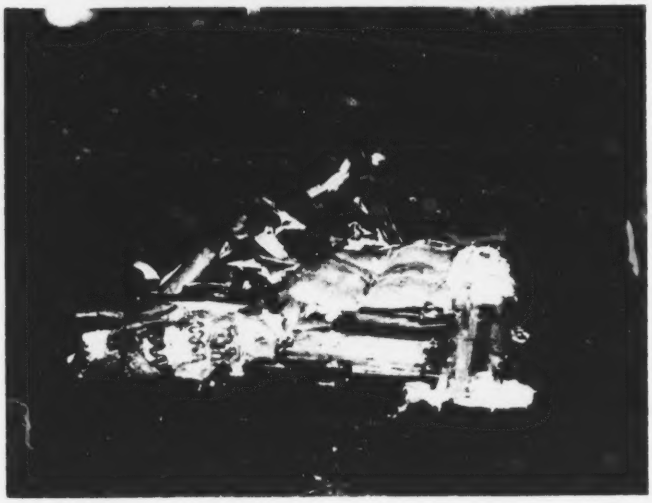

FIGURE 70. The remains of a vinyl covered rocking chair which were successfully collected by the PTC system.

following items:

- Wood pieces,
- Curtain rods,
- Wire racks,
- A mechanical adding machine,
- A large piece of cardboard (3 ft by 4 ft approximately),
- A shopping basket,
- Plastic pipes,
- A foot weight from a weight lifting set, and
- Parts of a vinyl covered rocking chair.

However, many objects smaller that these items caused chute and discharge valve blockages. Newspaper, cardboard boxes, and coat hangers frequently initiated numerous malfunctions, even though, at times, these items were easily collected. Figure 71 shows three cardboard boxes and a curtain rod which caused one chute blockage. Figure 72 shows a typical discharge valve blockage, with a large cardboard box creating this problem.

System Capacity for Loadings and Scheduling --

The system appeared to be able to handle design loads without any problems. As for the actual loading, the system operated satisfactory at 18 cycles per day. The results from the optimum scheduling tests, used to determine if the system could perform adequately with a reduced number of cycles, showed that the optimum operating schedule could be between seven to nine cycles per day. A feasible operating schedule for seven daily cycles could be cycling the PTC system once every two hours from 8 AM to 2 PM and from 5 PM to 9 PM. A possible operating schedule for nine daily cycles might be from 7 AM to 11 PM, with the PTC system operating once every two hours. Further tests should be conducted to insure that these operating schedules will provide for a reasonably high level of service. With a fewer number of daily cycles, operating costs could be reduced as well as prolonging component life.

The results obtained from the load capacity test, which determined the maximum density of refuse which could be safely collected by the PTC system, were compared to the design specifications. To present the test results, a regression line for transport velocity versus density was generated and is shown in Figure 73. The procedure to determine the regression line is reported in Appendix J. The test showed that as the

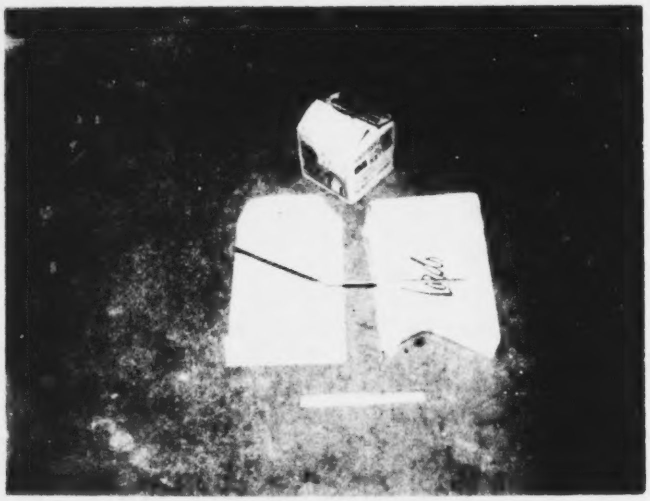

FIGURE 71. Three cardboard boxes and a curtain rod which created a chute blockage at Shelley A. A ruler is in the foreground to show the sizes of the objects.

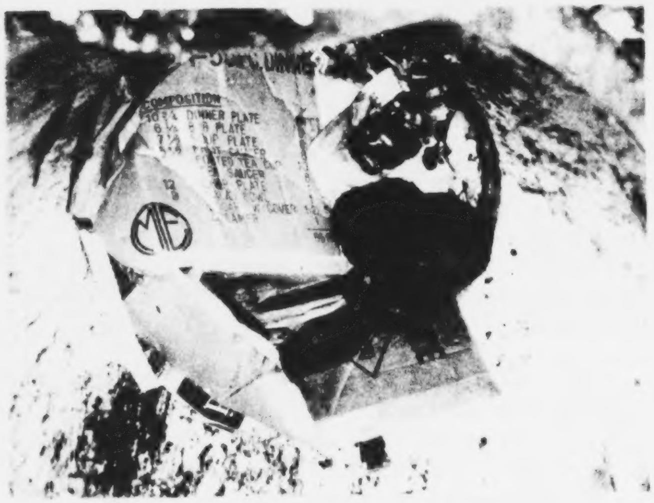

FIGURE 72. A large, bulky cardboard box causing a typical discharge valve blockage.

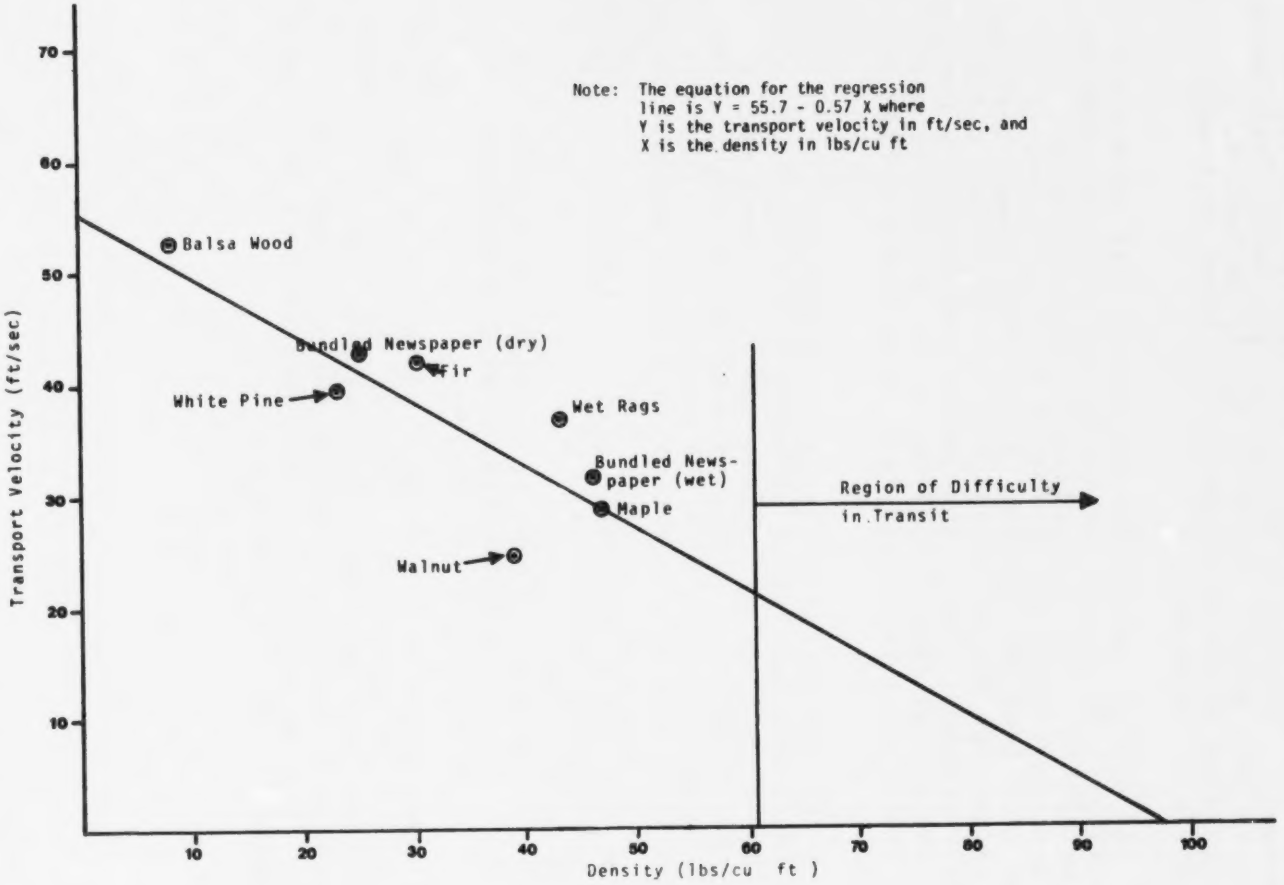

FIGURE 73. Transport velocity vs. density for refuse samples used in the load capacity test.

density of a refuse sample approached 60 pounds per cubic foot, the sample experienced difficulty in being easily collected. However, in the presence of other refuse, the sample was easily transported. Solid waste with density ranging to 100 pounds per cubic foot, when moved in this manner, could be easily collected, as demonstrated by brick fragments and rocks that were successfully collected.

The design specifications stated that refuse with a density of 50 pounds per cubic foot must be colected by the system. The load capacity test determined that the transport velocity of refuse with this density was about 27.2 feet per second. Experience showed that the PTC system had little difficulty in collecting refuse of this density. Thus, the system did favorably comply with the design specifications in the ability to collect overweight, oversized, and other bulky solid waste.

System Ability to Handle Dangerous Materials -- There are many types of solid waste which are prohibited from the PTC system and are classified as dangerous materials. Signs were posted on every charging station door to inform the tenants that the following items may not be placed in the PTC system:

- Lighted matches, cigars or cigarettes;
- Carpet sweepings;
- Oil soaked rags;
- Empty paint cans or aerosol containers; and
- Any other flammable, highly combustible, or explosive substance.

These types of solid waste could damage the system and injure the personnel. However, tenants did dispose of aerosol cans, and there were no problems in the ability of the system to safely collect these cans. Figure 74 shows a sample of the aerosol cans which were collected by the PTC system.

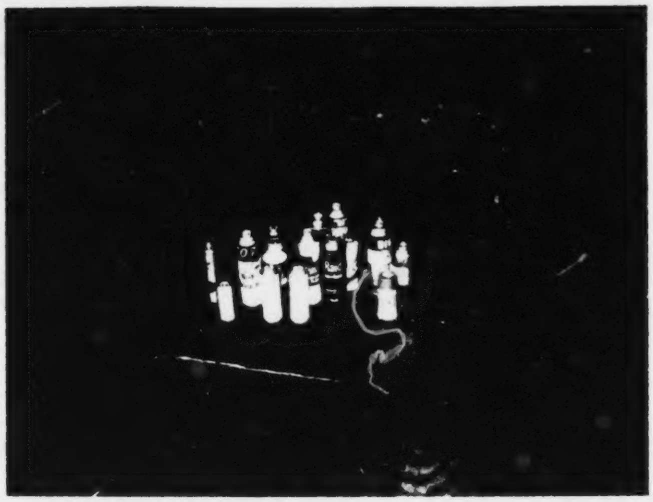

FIGURE 74. A sample of the aerosol cans that were safely collected by the PTC system.

System Adaptability to Recycle Specific Solid Waste -- The PTC system could be modified to recycle specific classes of solid waste, without major design changes and with reasonable success. The modifications would most likely be located at the collection hopper. When refuse entered the hopper, solid waste was circulated by the air stream such that the denser materials fell to the bottom. Thus, light refuse, such as paper bags, newspapers, and cardboard, was above the heavier refuse. These paper products could be easily collected for recycling. Other equipment could be installed to collect the metals and plastics from the refuse.

Observations indicated that glass reclaimed at the collection hopper may not be the most effective method. Glass objects put into the system usually become shattered. Results of the composition tests indicated that approximately one half of the refuse classified as fines was composed of glass. Equipment could be added to gather the glass collected by the PTC system for recycling. However, it would be more practical as well as more profitable to educate tenants to segregate glass at the chute charging stations. More glass could be collected in this manner and it would be of a better quality for recycling purposes.

The estimated amount of refuse that could be extracted from the PTC system for recycling is presented in Table 33. Refuse was classified into paper, glass, metal, and plastics. It might be possible to recycle 80 percent of the refuse; however, the economics for recycling these materials must be carefully considered to determine whether it is feasible.

System Ability to Recover Valuable Items --
There is a limited capability for recovering valuable items which have been mistakenly placed in the system; however, the probability of retrieving an undamaged item is small. The effort required to recover an object depends on system operations. If the object is still in the chute storage section (a compartment where refuse is accumulated for a chute between cycles), it is a simple matter of removing the section and sorting the refuse. If a collection cycle has been completed, the task of recovering the lost item becomes more difficult. The refuse container must be opened and the refuse manually sorted. Since the refuse for the entire site is compacted into the refuse container, chances of locating any particular item are poor.

Adequacy of Safety Equipment --
The design of the PTC system incorporated many control and safety features to prevent component and plant failures, service interruptions, fires, and personnel injuries. The design specifications stated specific conditions for these features. The system experienced several incidents which demonstrated the effectiveness of the safety equipment to avert any problem.

Every component in the PTC system was designed and constructed according to recognized national and industrial standards and applicable local codes. The collection hopper, dust collector, main transport line and additional components under vacuum or pressure conditions were designed and constructed according to good practices, as well as suitable ASME Boiler and Pressure Vessel Code and ANSI standards. All wiring and electrical components were designed and constructed according to the National Electric Code, local codes, and with the appropriate UL approved components.

Table 33. ESTIMATED AMOUNT OF SOLID WASTE WHICH COULD BE COLLECTED FOR RECYCLING FROM THE PTC SYSTEM

Refuse Type	Percent Composition By Weight	Annual Amount of Recycled Materials[1]
Paper	59.5	147.7 tons/yr
Glass[2]	7.4	18.4
Metal	8.0	19.9
Plastic	4.2	10.4
Total	79.1	196.4

---

[1] *The site generates 248.3 tons of solid waste per year.*

[2] *The amount of glass includes an estimated portion of 50 percent of the fines.*

Fire detectors and sprinkler systems, meeting NEPA and local codes, were installed to prevent extensive fire damage to the PTC system. Sprinkler systems were placed in all chute charging stations, discharge valve rooms, the PTC equipment room, the compactor room, and building trash chutes.

The PTC system was designed and constructed with drainage and overflow features at the CEB and discharge valve rooms to prevent service interruptions caused by water infiltration. This would permit rapid drainage and prevent flooding of all electrical and mechanical equipment if there was a breakage of a water containing system. Landscaping around the CEB was designed so that runoff, caused by normal and abnormal rainfalls, would be quickly carried away from the building.

The design of the PTC system included considerations for safe and effective operation, and provisions for ample room to service and repair all components. Performance of required maintenance activities would not place site personnel in close proximity to rotating machinery, hot surfaces, sharp projections, low clearances, and exposed electrical wiring.

Fire Detection and Sprinkler Systems--Problems were experienced with the fire detection and sprinkler systems. Two specific problems might have been avoided through a more careful building inspection. One problem was that a fire, which started in the trash chute at Descon Concordia on December 1, 1974, failed to activate the sprinkler system. Another problem was several sprinkler heads in the charging stations at Shelley A were found to be wrapped in plastic.

The high temperature alarm cable for the number 2 main exhauster ignited on January 30, 1975. Site personnel reported that severe vibrations from the exhauster chaffed the cable insulation and that a short caused the fire. Figure 75 shows a high temperature alarm cable.

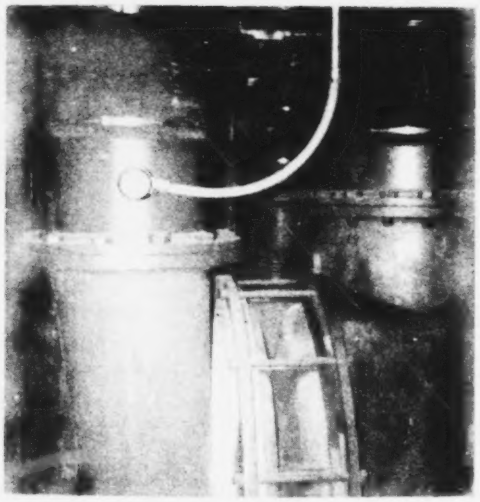

FIGURE 75. High temperature alarm cable for a main exhauster, similar to the one that ignited.

Water Infiltration and Drainage--The drainage and overflow features incorporated in the PTC system could not handle the variety of water problems experienced at the site. The design specifications only considered one aspect of water oriented problems. There was a provision to protect the PTC system when a water break in a second system at the CEB occurred. There were numerous cases on the site, exterior to the CEB, that the specifications did not address.

Water infiltration into the main transport line through vaults and access plates created a variety of problems. In particular, one vault would completely fill with water after every rainstorm. The combination of the hydrostatic head over the access plate and the vacuum in the main transport line caused water to penetrate into the line. The designs of the vaults and the main transport line had no provisions for the removal of water. Therefore, in many cases, private contractors with the necessary skills and equipment were required to remove the water that had infiltrated into the main transport line.

The floor drains for the discharge valve rooms should be independent from any other plumbing lines. The floor drain at Shelley B West was connected to a roof drain. During one severe rainstorm, the drain was blocked and stormwater flooded the discharge valve room. The water level was over the discharge valve, and water entered the main transport line. This created mechanical and electrical problems with the PTC system.

The designs of future PTC systems should consider better methods and procedures to resolve all drainage and overflow problems. The site experienced long downtimes and extensive labor efforts to remove water from the main transport line. Future applications of PTC systems should investigate more controls for drainage and overflow problems.

System Ability to Perform Under Low Temperatures --
It was observed that the system did not operate properly under conditions of low temperature. The main problems were with the compactor and the pneumatic lines. As mentioned previously, the compactor was housed in a room that was not heated. The hydraulic oil used in the compactor operates in temperatures near 70°F. At lower temperatures, the oil became more viscous and caused frequent compactor failures.

The air inlet and discharge valves were operated by pneumatic lines. These lines were also located in rooms that were not heated. At low temperatures, moisture in the pneumatic lines froze and caused controls to malfunction.

Service Life

The service life for the PTC system was based on the service life of the components considered crucial for system operations. These components were the main transport line, the discharge valves, and the compactor. Preliminary life cycle estimates for these critical components, based on the technical data gathered during the monitoring program, are compared to the service life as stated in the design specifications. These specifications stated that the service life shall be forty years.

Main Transport Line --
The two test sections for the main transport line were investigated for wear during the initial and final characterization tests. Detailed calculations to predict the service life for the line are presented in

Appendix K. The original wall thickness was 0.500 inch and the annual wall erosion rate was 0.012 inch. It was determined that a failure would occur if the wall thickness was less than 0.070 inch. This condition could be expected to occur after 36 years of operation, four years less than the design life of 40 years. This was determined by:

$$\text{service life} = \frac{0.500 \text{ inch} - 0.070 \text{ inch}}{0.012 \text{ inch/year}}$$

$$= 36 \text{ years}$$

Discharge Valves --

The discharge valves at Shelley A, Descon Concordia, and Camci were investigated for wear. These stations serviced all the MFHR buildings and were assumed to experience the greatest amount of wear of any discharge valve. In particular, the discharge valve plate was studied, since this part showed the most signs of wear. The calculations to predict the service life for the discharge valves are presented in Appendix L. The estimated service life for the plates, and thus for the discharge valves, ranged from 58 to 106 years.

Compactor --

The compactor ram, which appeared to experience the greatest amount of wear for the compactor unit, was investigated. The top plate of the ram was measured for thickness by the Branson Caliper, an ultrasonic device. The original plate thickness was 0.255 inch thick, and the annual wear rate was 0.0067 inch. It was assumed that the top plate could wear completely through before operating problems would occur. The service life for the compactor was found to be 38 years, two years less than the design life of 40 years. This was determined by:

$$\text{service life} = \frac{0.255 \text{ inch}}{0.0067 \text{ inch/year}} = 38 \text{ years}$$

Results of Wear Measurements --

The preliminary life cycle estimates showed that the main transport line and the compactor may fail before the designed service life of 40 years ends. It is concluded that the compactor could be easily repaired. However, a main transport line failure would create severe and costly problems for several reasons:

- Locating the failed section,
- Excavating in order to reach the section,
- Repairing and/or replacing the failed section,
- Backfilling to cover the section, and
- Providing an alternative refuse collection service during the repair efforts.

ECONOMIC EVALUATION

The economic data used for the evaluation were obtained from the Department of Housing and Urban Development, site management, and other sources during 12 months of the monitoring period. The costs incurred by the PTC system were disaggregated into capital, operational, and maintenance costs and compared to three types of conventional solid waste management systems commonly used in residential complexes such as the Jersey City Operation Breakthrough site. The annualized costs for all four refuse collection systems are projected to the year 1995 to show the economic relationships between the systems. Furthermore, the observed system costs were compared to design estimates.

Annual Cost

PTC System --
The cost to operate the PTC system during the monitoring period of January 1 to December 31, 1975 were reported in Table 28. The system costs were $120,021 to collect 248.3 tons of refuse during the monitoring program. As previously mentioned, in Section IV, all economic data have been adjusted to October 1975 dollars.

Conventional Systems --
Three types of alternative refuse collection systems were used for comparison. One system, system A, consisted of a chute fed compactor unit at the base of each MFHR building and containers at the remaining buildings and other locations. Table 34 provides a further description of the system. The site management provided a bulk waste collection service, maintenance of container pens, and labor to move the container to areas accessible to the collection vehicles. The manpower required to operate this system is shown in Table 35.

Table 34. DESCRIPTION OF SOLID WASTE MANAGEMENT SYSTEM ALTERNATIVES A AND B

Location		Chute Fed Compactor and Two Containers	Chute Fed Containers	Loose Refuse Per Week (Cubic Yards)	Changes Per Week
Camci	153 MFHR	X		31.9	3
Descon Deck West	12 MFLR		X	5.0	2
Descon Deck East	24 MFMR		X	13.4	5
Descon Concordia	105 MFHR	X		20.2	2
Shelley B West	10 MFMR		X	3.8	2
Shelley B East	30 MFMR		X	11.3	4
Shelley A	152 MFHR	X		42.8	3
Shelley A South[1]			X	2.5	2
				130.9	23

---

[1] *This building was a small shed used to collect recreational and yard waste only.*

Table 35. SITE MANPOWER REQUIREMENTS FOR SYSTEM ALTERNATIVE A

Task	Man-hours Per Task		Man-hours Per Year
Change containers	1.5 man-hours per change		1,794
Daily collection	6.0 man-hours per day		2,190
Clean pens	0.5 man-hour per pen per week		130
Clean compactor rooms	0.5 man-hour per room per week		104
Repair pens	2.0 man-hours per week		104
			4,322
Labor supervision at 15 percent of other labor requirements			649
		Total	4,971

System B is similar to system A (Table 34) except for manpower requirements. In system A, the site management provides all the labor. However, in system B, a private contractor is responsible for moving containers to and from the collection vehicles. Requirements for the manpower needed are given in Table 36.

System C consisted of vertical trash chutes with containers at their bases. No compactor was utilized and refuse merely collected in the containers. This system is described further in Table 37. The site management provided a bulk waste collection service, maintenance of container pens, and labor to move the containers to areas accessible to the collection vehicles. The manpower required by the system is presented in Table 38.

The annual costs for systems A, B, and C are presented in Tables 39, 40, and 41 respectively.

Cost Analysis

Comparison with Conventional Systems --

The comparison of the annualized costs of the PTC system with the three refuse collection systems is shown in Table 42. It can be seen that the PTC system is, depending on the system it is compared to, from 1.6 to 4.6 times as expensive to operate. This is based upon the observed loading of 248.3 tons per year. The costs are disaggregated into the following categories and are presented in Figure 76.

- Capital cost,
- Site labor cost,
- Hauling and sanitary landfill cost, and
- Contingency cost.

The significantly higher cost of the PTC system is attributed to the capital cost. This cost greatly exceeded the annual cost for the three conventional systems and accounted for about three-fourths of the annual cost for the PTC system.

The annual costs for all four systems were projected to the year 1995 in Figure 77. Indices for capital, labor, material, and energy costs were generated for the years 1975 to 1995 from previous work (see Appendix N). These data were used to project the future operating costs of each refuse collection system, so that these costs can be compared.

Table 36. SITE MANPOWER REQUIREMENTS FOR SYSTEM ALTERNATIVE B

Task	Man-hours Per Task	Man-hours Per Year
Daily collection	6.0 man-hours per day	2,190
Clean pens	0.5 man-hour per pen per week	130
Clean compactor rooms	0.5 man-hour per room per week	104
Repair pens	2.0 man-hours per week	104
		2,528
Labor supervision at 15 percent of other labor requirements		379
	Total	2,907

Table 37. DESCRIPTION OF SOLID WASTE MANAGEMENT SYSTEM ALTERNATIVE C

Location		Number of 3 Cubic Yard Containers	Loose Refuse Per Week (Cubic Yards)	Changes Per Week
Camci	153 MFHR	3	31.9	15
Descon Deck West	12 MFLR	1	5.0	2
Descon Deck East	24 MFMR	2	13.4	6
Descon Concordia	105 MFHR	2	20.2	10
Shelley B West	10 MFMR	1	3.8	2
Shelley B East	30 MFMR	1	11.3	4
Shelley A	152 MFHR	4	42.8	20
Shelley A South[1]		1	2.5	1
		15	130.9	60

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[1] *This building was a small shed used to collect recreational and yard waste only.*

Table 38. SITE MANPOWER REQUIREMENTS FOR SYSTEM ALTERNATIVE C

Task	Man-hours Per Task	Man-hours Per Year
Change containers	1.5 man-hours per change	4,680
Daily collection	6.0 man-hours per day	2,190
Clean pens	0.5 man-hour per pen per day	390
Clean container room	0.5 man-hour per week	26
Repair pens	7.5 man-hours per week	390
		7,676
Labor supervision at 15 percent of other labor requirements		1,152
	Total	8,828

Table 39. ANNUAL COST FOR THE REFUSE COLLECTION SYSTEM ALTERNATIVE A

	Initial Cost	Lifetime (Years)	Carrying Charge	Annual Cost	Percent
Capital Costs					
3 compactors and 6 containers (2 cu yd each)	$19,230	10	0.145	$ 2,815	8.3
5 containers (3 cu yd each)	1,050	7.5	0.179	188	0.6
1 container (25 cu yd)	2,050	7.5	0.179	367	1.2
5 pens for 3 cu yd containers	1,350	7.5	0.179	242	0.8
Building chutes and charging stations	22,623	40	0.079	1,796	5.6
				$5,408	17.0
Operating and Maintenance Costs					
Labor-- 4,322 man-hours/year at $3.00/hr with 20 percent fringes				$15,559	48.9
Labor supervision-- 649 man-hours/year at $5.00/hr with 20 percent fringes				3,894	12.2
Compactor repair material at 1 percent of initial cost				193	0.6
Pen repair material at 1 percent of initial cost				14	0.0
Hauling and sanitary landfill fees				6,765	21.3
				$26,425	83.0
				$31,833	100.0

Table 40. ANNUAL COST FOR THE REFUSE COLLECTION SYSTEM ALTERNATIVE B

	Initial Cost	Lifetime (Years)	Carrying Charge	Annual Cost	Percent
Capital Costs					
3 compactors and 6 containers (2 cu yd each)	$19,320	10	0.145	$ 2,815	10.7
5 containers (3 cu yd each)	1,050	7.5	0.179	188	0.7
1 container (25 cu yd)	2,050	7.5	0.179	367	1.4
5 pens for 3 cu yd containers	1,350	7.5	0.179	242	0.9
Building chutes and charging stations	22,623	40	0.079	1,796	6.9
				$5,408	20.6
Operating and Maintenance Costs					
Labor-- 2,528 man-hours/year at $3.00/hr with 20 percent fringes				$ 9,101	34.7
Labor supervision-- 380 man-hours/year at $5.00/hr with 20 percent fringes				2,280	8.7
Compactor repair material at 1 percent of initial cost				193	0.7
Pen repair material at 1 percent of initial cost				14	0.1
Hauling and sanitary landfill fees				9,235	35.2
				$20,823	79.4
				$26,231	100.0

Table 41. ANNUAL COST FOR THE REFUSE COLLECTION SYSTEM ALTERNATIVE C

	Initial Cost	Lifetime (years)	Carrying Change	Annual Cost	Percent
CAPITAL COSTS					
15 containers (3 cu yd each)	$ 3,150	7.5	0.179	564	0.7
1 container (25 cu yd)	2,050	7.5	0.179	367	0.5
15 pens for 3 cu yd containers	4,050	7.5	0.179	726	1.0
Building chutes and charging station	22,623	40	0.079	1,796	2.4
				3,453	4.6
OPERATING AND MAINTENANCE COSTS					
Labor--7,676 man-hours/year at $3.00/hour with 20% fringes				27,634	37.0
Labor supervision--1,152 man-hours/year at $5.00/hour with 20% fringes				6,912	9.2
Pen repair material at 1% of initial cost				40	0.1
Hauling and sanitary landfill fees				36,660	49.1
				71,246	95.4
				74,699	100.0

Table 42. COMPARATIVE ANNUAL COSTS FOR THE PTC SYSTEM AND THREE CONVENTIONAL SOLID WASTE MANAGEMENT SYSTEMS

System	Annual Cost	Cost/ Dwelling Unit/ Year	Cost/ Capita/Year	Cost/Ton
PTC System	$120,021	$247	$96	$483
System A	31,833	66	25	128
System B	26,231	54	21	106
System C	74,699	154	60	301

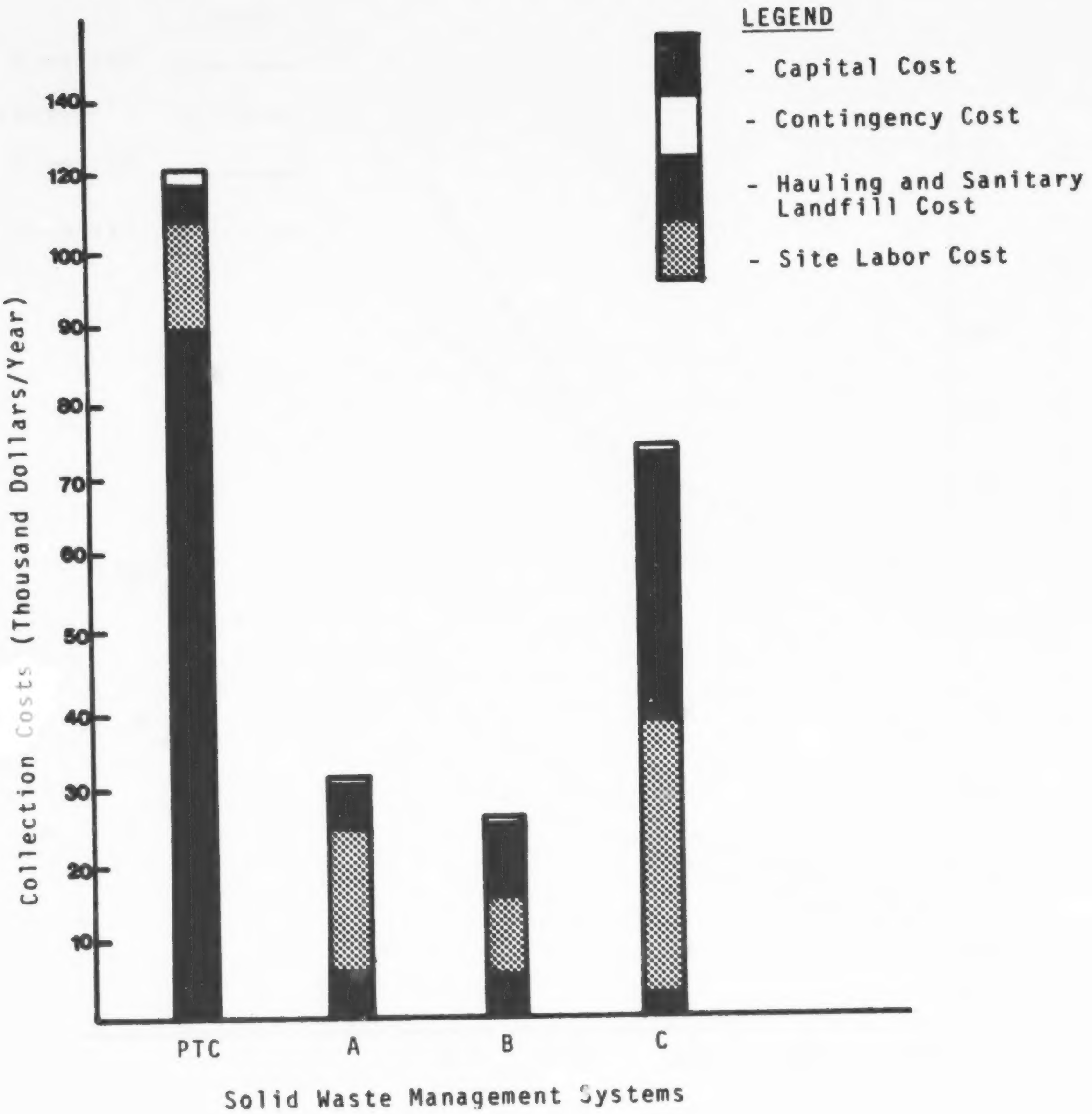

FIGURE 76. Annual costs for the PTC system and three alternative conventional solid waste management systems.

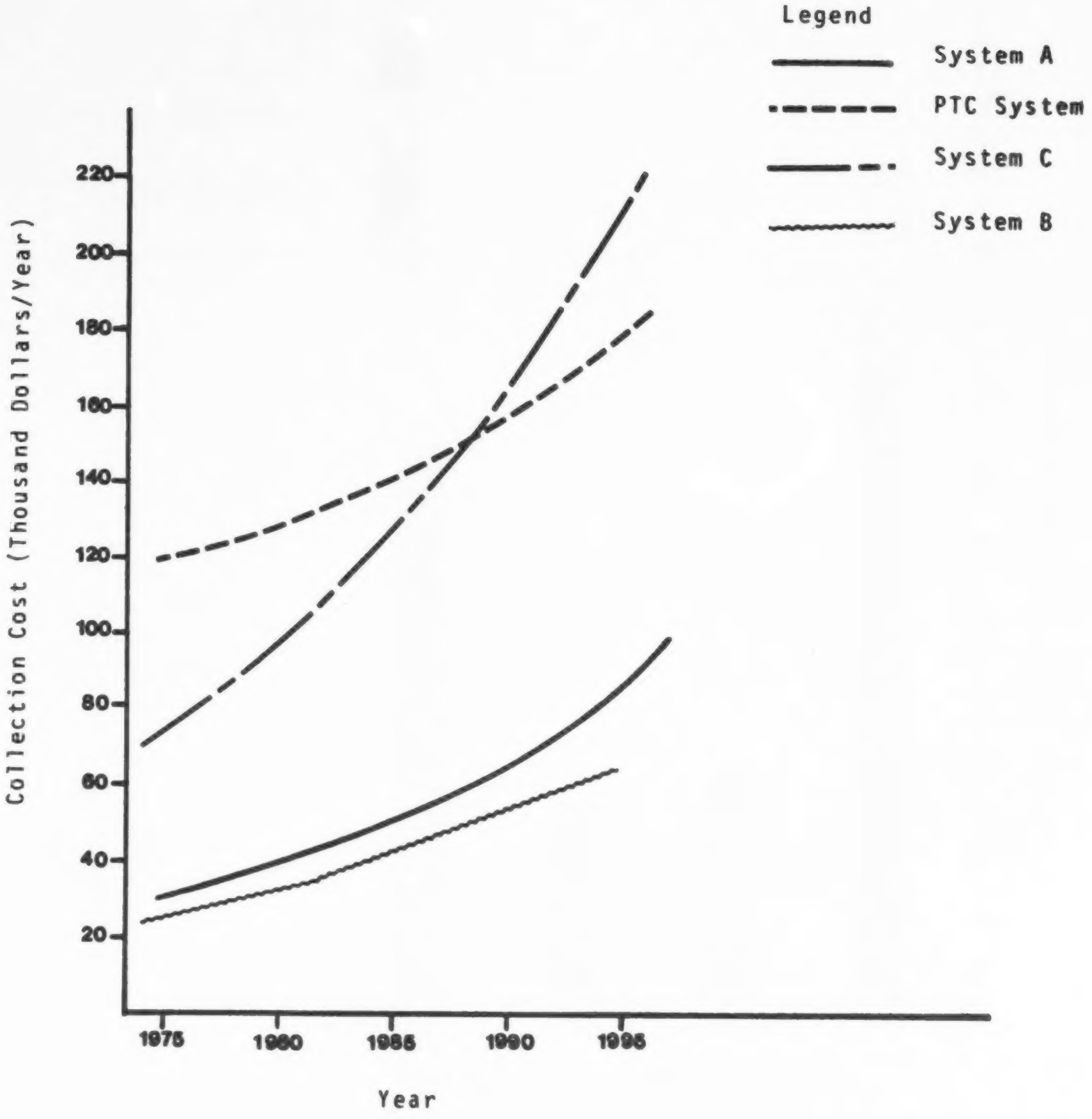

FIGURE 77. Annual cost projections for the PTC system and three alternative conventional solid waste management systems.

The projected annual cost for the PTC system increased at about the same rate as systems A and B. Both of these conventional systems used compactors. The annual cost for the remaining system, system C, increased at about twice the rate as the PTC system. This system was highly labor intensive.

Comparison with Design Estimates -- The PTC system was designed to be cost effective for the designed loading of 1300 tons of refuse per year. In addition, the system components were designed to handle an additional 25 percent in loading over its life. Thus, the system could collect a total of 1600 tons of refuse per year.

The analysis showed, as demonstrated in Figure 78, that the PTC system could be cost effective if it is operated at the design capacity. Operating at the observed loading of 248.3 tons per year, the cost to collect and dispose of refuse was $483 per ton. However, if the system operated at the design loading of 1300 to 1600 tons of refuse per year, the cost would vary between $116 to $99 per ton respectively. Comparing these figures to the costs of operating the three conventional systems at the design loadings for the PTC system, it can be seen that operating the PTC system at design loadings would be cost effective.

System	Cost in dollars/ton
System A	123 - 131
System B	104 - 109
System C	331 - 341
PTC System	99 - 116

RESIDENT ACCEPTANCE EVALUATION

The resident acceptance of the PTC system was presented in a separate document. The results from the previous report are summarized to investigate the following subjects:

- The type of resident at the site;
- The resident awareness of the requirements of the PTC system; and
- The resident and management acceptance of the PTC system.

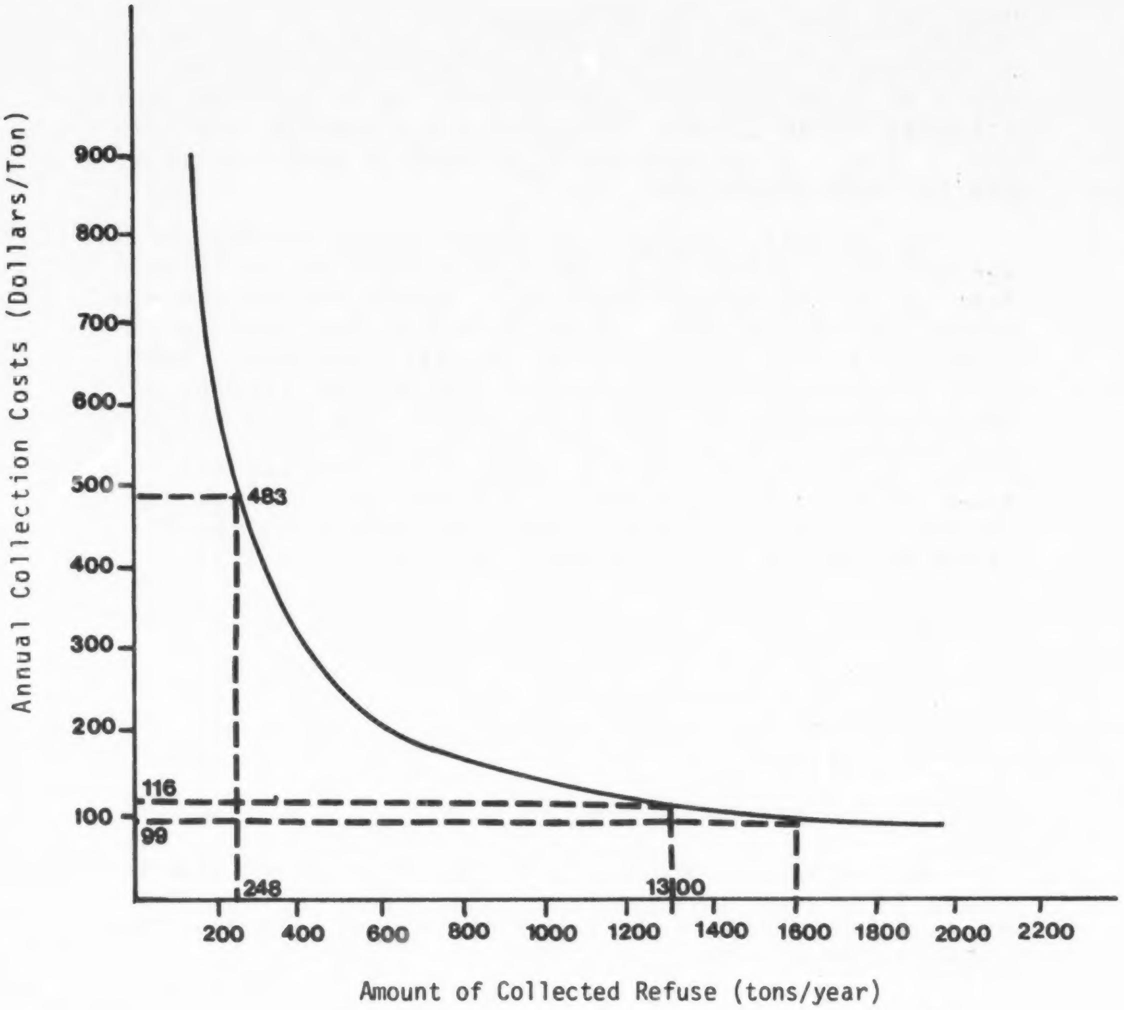

FIGURE 78. Annual collection costs for the PTC system vs. amounts of refuse collected.

A representative sample of the households for 164 out of a total of 486 dwelling units at the site were surveyed.

Type of Resident

The residents at the site are described by retirement status, number of adults, and number of children. About 24 percent of the residents were retired. A distribution of residents by numbers of adults and children is presented in Table 43. A typical dwelling unit has roughly about two adults and one child.

Resident Awareness of System Requirements

The residents were surveyed to determine their awareness of the requirements for the PTC system. The results of the survey indicated that almost all of the tenants were cognizant of the use and capabilities of the PTC system. The survey indicated that 98 percent of the residents realized that the site management was responsible for the operations of the system. Furthermore, 95 percent of the residents were aware that large, bulky waste would be collected by contacting the site management. However, there was some confusion on the part of the residents about the requirement of segregating refuse.

The survey showed that the residents were confused over the policy of segregating refuse before disposal in the trash chutes. Table 44 shows the percentage of residents that actively participated in refuse separation. Out of the 164 residents interviewed, 108 or 66 percent said they participated in separating refuse while, 56 or 34 percent said they did not.

It was observed during the monitoring period that some tenants were not only more aware of their responsibilities to the PTC system, but more responsive as well. These tenants posted their own signs to inform other residents of how to use the system properly. Figure 79 shows some of the typical signs found at the charging stations.

Resident and Management Acceptance of the System

The residents and site management were interviewed to determine whether they felt that the PTC system adequately collected refuse. The results of the residents' evaluation of the system is shown in Table 45.

Table 43. POPULATION DISTRIBUTION OF RESIDENTS

Number 'of Adults per Unit	Number of Units Sampled	Number of Adults	Number of Children per Unit	Number of Units Sampled	Number of Children	Total Number of Persons
0	0	0	0	98	0	0
1	35	35	1	36	36	71
2	113	226	2	20	40	226
3	12	36	3	8	24	60
4 or more	4	≥16	4 or more	2	≥8	≥24
	164	≥ 313		164	≥ 108	≥ 421

Table 44. EXTENT OF RESIDENT PARTICIPATION IN SEPARATING SOLID WASTE

Item[1]	Number of Residents Participating[2]	Percent of Resident Participation
Glass	96	58.5
Bulky waste	81	49.4
Plastic	27	16.5
Food waste	0	0.0
Newspaper and magazines	90	54.9
Cans	1	0.6

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[1] *Tenants separated their refuse into these categories.*

[2] *A total of 164 residents were interviewed.*

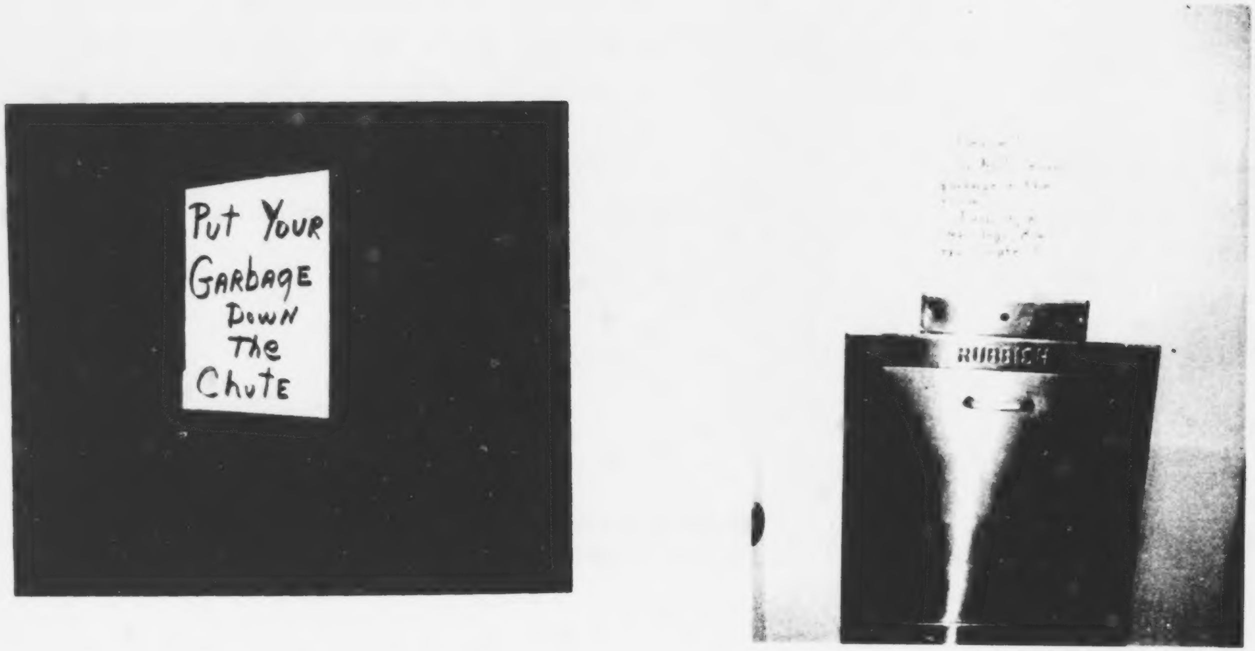

Put Your Garbage Down The Chute
RUBBISH

FIGURE 79. Typical signs posted by the tenants to inform other tenants to be more considerate when they dispose their refuse.

Table 45. RESIDENT EVALUATION OF PTC SYSTEM ADEQUACY

Problem Description		Number of Residents Reporting Problems[1]	Percent of Dissatisfied Residents
Chute blockages		23	14.0
Small size of chute charging stations		9	5.5
Did not use PTC system		2	1.2
Compactor mechanical problems		1	0.6
Small size of chute door opening		1	0.6
	Total	36	21.9

---

[1] *A total of 164 residents were interviewed.*

The evaluation showed that over one percent of the tenants did not use the PTC system, and that about 78 percent of the tenants were satisfied with the performance of the system. There was one resident who felt that the PTC system was environmentally inadequate, but did not state the deficiencies.

The site management felt that their services could have been minimized if the PTC system had performed properly and if the tenants had correctly used the system. Due to the considerable number of system malfunctions and the large quantities of litter in the discharge valve rooms and charging stations, the management had to provide extensive labor efforts to repair and clean the system. The management also felt that many of these efforts were attributable to the low level of resident cooperation in properly utilizing the system. Several specific problems were cited. They include:

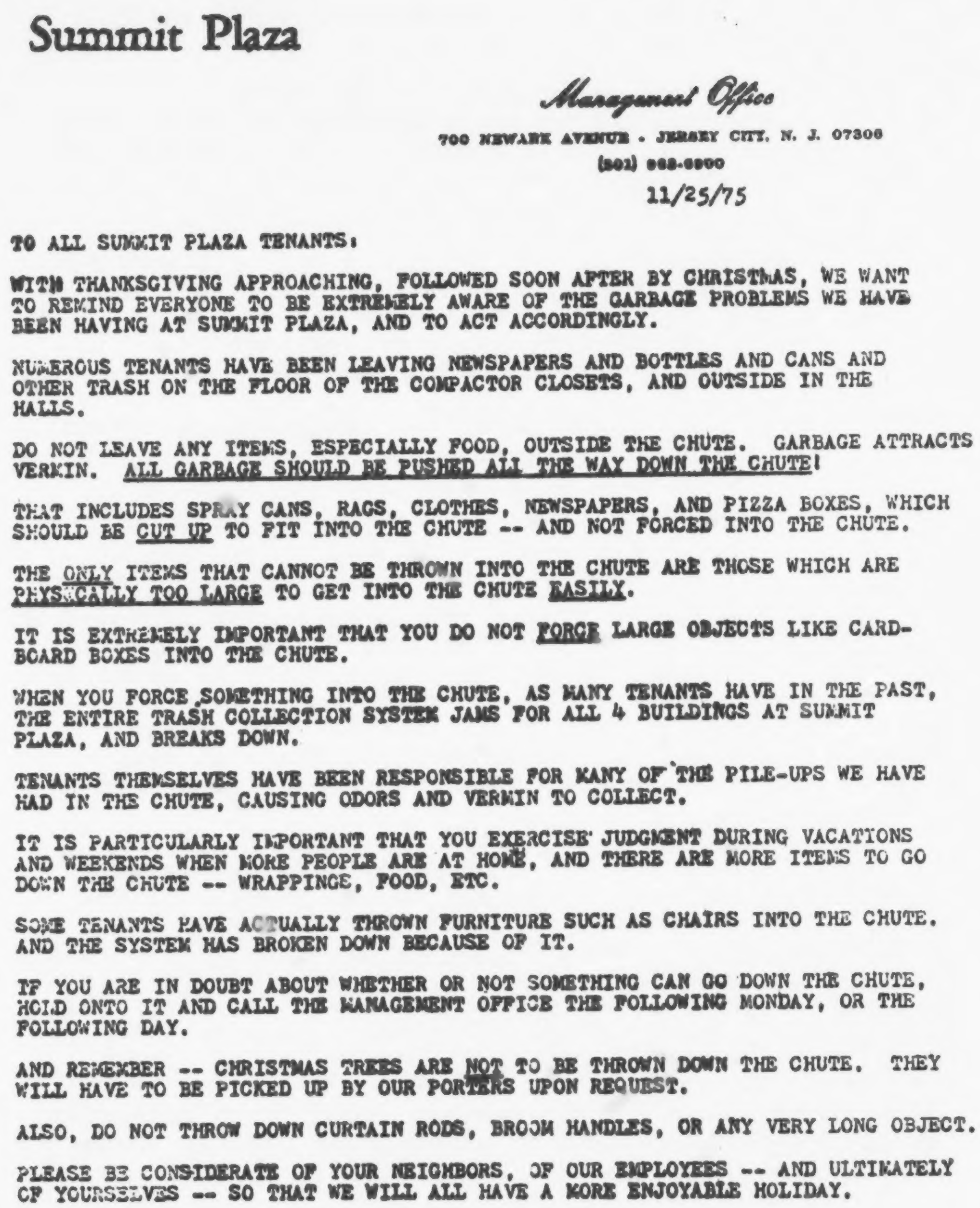
- Residents breaking PTC system components by forcing large, bulky wastes into the chute door;
- Residents causing chute blockages by not pushing refuse all the way down the chute;
- Residents leaving food wastes and moist garbage on charging station floors or in hallways and stairways; and
- Residents improperly wrapping refuse which created unsanitary and unhealthy conditions in discharge valve rooms, especially during periods of operating problems.

The site management implemented many policies to correct these problems by educating residents in the proper use of the PTC system. One example of these policies is a notice (Figure 80) posted on all charging stations doors, that listed certain system regulations.

ENVIRONMENTAL EVALUATION

The PTC system was examined to determine the environmental effects of the system. The following topics were considered:

- Sanitation effects such as litter, cleanliness, odor, and presence of rodents and vermin;



Summit Plaza

Management Office

700 NEWARK AVENUE · JERSEY CITY, N. J. 07306
(201) 963-6900

11/25/75

TO ALL SUMMIT PLAZA TENANTS:

WITH THANKSGIVING APPROACHING, FOLLOWED SOON AFTER BY CHRISTMAS, WE WANT TO REMIND EVERYONE TO BE EXTREMELY AWARE OF THE GARBAGE PROBLEMS WE HAVE BEEN HAVING AT SUMMIT PLAZA, AND TO ACT ACCORDINGLY.

NUMEROUS TENANTS HAVE BEEN LEAVING NEWSPAPERS AND BOTTLES AND CANS AND OTHER TRASH ON THE FLOOR OF THE COMPACTOR CLOSETS, AND OUTSIDE IN THE HALLS.

DO NOT LEAVE ANY ITEMS, ESPECIALLY FOOD, OUTSIDE THE CHUTE. GARBAGE ATTRACTS VERMIN. ALL GARBAGE SHOULD BE PUSHED ALL THE WAY DOWN THE CHUTE!

THAT INCLUDES SPRAY CANS, RAGS, CLOTHES, NEWSPAPERS, AND PIZZA BOXES, WHICH SHOULD BE CUT UP TO FIT INTO THE CHUTE -- AND NOT FORCED INTO THE CHUTE.

THE ONLY ITEMS THAT CANNOT BE THROWN INTO THE CHUTE ARE THOSE WHICH ARE PHYSICALLY TOO LARGE TO GET INTO THE CHUTE EASILY.

IT IS EXTREMELY IMPORTANT THAT YOU DO NOT FORCE LARGE OBJECTS LIKE CARDBOARD BOXES INTO THE CHUTE.

WHEN YOU FORCE SOMETHING INTO THE CHUTE, AS MANY TENANTS HAVE IN THE PAST, THE ENTIRE TRASH COLLECTION SYSTEM JAMS FOR ALL 4 BUILDINGS AT SUMMIT PLAZA, AND BREAKS DOWN.

TENANTS THEMSELVES HAVE BEEN RESPONSIBLE FOR MANY OF THE PILE-UPS WE HAVE HAD IN THE CHUTE, CAUSING ODORS AND VERMIN TO COLLECT.

IT IS PARTICULARLY IMPORTANT THAT YOU EXERCISE JUDGMENT DURING VACATIONS AND WEEKENDS WHEN MORE PEOPLE ARE AT HOME, AND THERE ARE MORE ITEMS TO GO DOWN THE CHUTE -- WRAPPINGS, FOOD, ETC.

SOME TENANTS HAVE ACTUALLY THROWN FURNITURE SUCH AS CHAIRS INTO THE CHUTE. AND THE SYSTEM HAS BROKEN DOWN BECAUSE OF IT.

IF YOU ARE IN DOUBT ABOUT WHETHER OR NOT SOMETHING CAN GO DOWN THE CHUTE, HOLD ONTO IT AND CALL THE MANAGEMENT OFFICE THE FOLLOWING MONDAY, OR THE FOLLOWING DAY.

AND REMEMBER -- CHRISTMAS TREES ARE NOT TO BE THROWN DOWN THE CHUTE. THEY WILL HAVE TO BE PICKED UP BY OUR PORTERS UPON REQUEST.

ALSO, DO NOT THROW DOWN CURTAIN RODS, BROOM HANDLES, OR ANY VERY LONG OBJECT.

PLEASE BE CONSIDERATE OF YOUR NEIGHBORS, OF OUR EMPLOYEES -- AND ULTIMATELY OF YOURSELVES -- SO THAT WE WILL ALL HAVE A MORE ENJOYABLE HOLIDAY.

FIGURE 80. Site management regulations on the usage of the PTC system.

- Air quality of the internal system air and of the exhaust air, including airborne particulates and viable particles;
- Noise levels produced by the refuse collection activities compared to background noise levels and acceptability to residential use of the system;
- Aesthetic qualities attibuted to the system; and
- Advantages of a reduced number of service vehicle visits to the site to pick up and dispose of refuse.

These subjects are compared to the conditions declared in the design specifications.

Sanitation Effects

The sanitation effects of the PTC system were observed and examined to determine whether the refuse collection activities of the system were more sanitary than conventional systems. The aspects studied in detail were litter, cleanliness, odor, and the presence of rodents and vermin. The system, generally, was clean. Nevertheless, the conditions around the discharge valve rooms and chute charging stations drastically deteriorated during periods of prolonged system malfunctions.

As was the customary procedure, some refuse such as large bulky items, cardboard boxes, glass bottles, and newspaper, were left as chute charging stations (Figure 81) and at designated pick-up areas outside the buildings. The site management provided a daily collection service for these items. Thus, the effects of litter, odor and vermin were minimal. However, the charging stations at the Descon Concordia and Camci buildings did have roaches. It was reported by the site management, that the roaches would first appear in the kitchens of new tenants and migrate over to these charging stations.

The discharge valve rooms were constantly littered with refuse that escaped from the chute storage sections. Since these discharge valve rooms were located in underground vaults, and not easily accessible to site

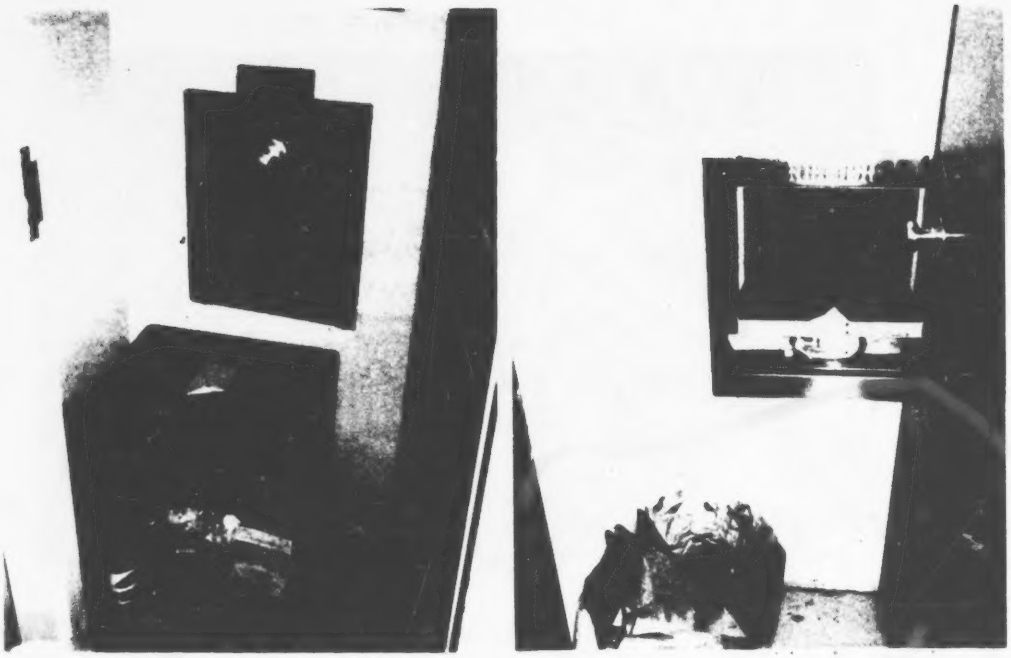


FIGURE 81. Refuse left at the charging stations which was collected daily by site personnel.

personnel as seen in Figure 82, the litter was not cleaned up. As a result, ants, roaches, and flies were prevalent. In particular, the discharge valve rooms at Descon Concordia experienced sanitation problems. The room was located near a mechanical room, which constantly had water seepage from traps and leaks in the steam lines. The combination of the hot, humid atmosphere and decaying refuse provided excellent breeding conditions for vermin.

The compactor room was also continually littered which was caused by site personnel. They would haul bulk waste to the room and dispose of it either in the open top container provided for the bulk waste or on the floor, as seen in Figure 83. The litter would not only fall into the channels for the container handling equipment and foul the chains and other equipment, but caused problems with odor, cleanliness, and vermin.

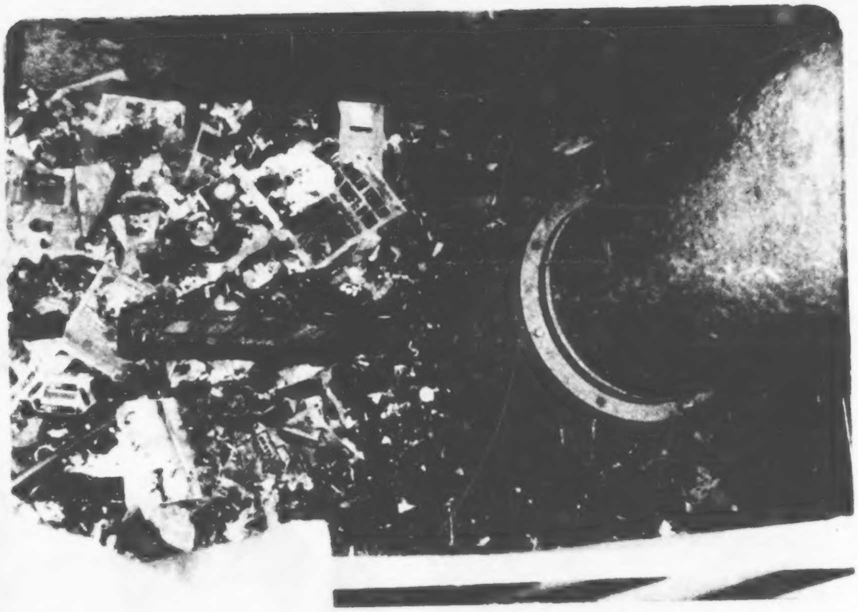


FIGURE 82. Discharge valve room at Camci showing the amount of litter in the room. The site personnel must climb down the ladder to clean the room.

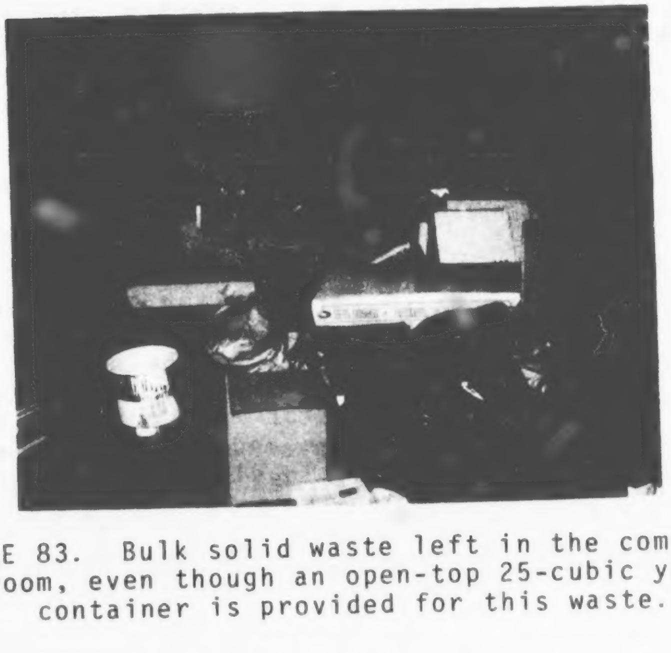


FIGURE 83. Bulk solid waste left in the compactor room, even though an open-top 25-cubic yard container is provided for this waste.

The sanitation effects such as litter, cleanliness, odor, and insects were compounded when the system experienced prolonged downtime. With the system not operating, site personnel had to collect refuse manually. To accomplish this, site personnel removed the chute storage sections. This allowed refuse from the chutes to fall freely into the discharge valve rooms (Figure 84). Then, the refuse could be picked up by hand. However, this contributed to unclean conditions, breeding places for vermin, and odors. Matters were intensified when the weather was hot and humid.

In an effort to improve this situation, site personnel attached large bags to the bottom of the storage sections, as shown in Figure 85. This helped to alleviate the sanitation problems in the discharge valve rooms, but in so doing caused another problem. As the bags became filled, the chute would fill up. Eventually the chute would become blocked and unable to accept more refuse. When this occurred, residents would leave their refuse at the chute charging stations and in the hallways (see Figure 86). This resulted in unclean and unhealthy conditions in the residential dwellings themselves. It should be noted that chute blockages during normal PTC system operations also caused these same conditions.

An effort was made by the site management to control the vermin at the site which also included the PTC system. An exterminator was employed to visit the complex monthly.

Air Quality --

The air pollution levels associated with the PTC system were measured and compared to ambient conditions and Federal regulations. The total airborne particulate matter in the system air and exhaust air were compared to the concentration in ambient air and the EPA National Ambient Air Quality Standards (Federal Regulations CFR 50: 36 FR22384, November 25, 1971). Table 46 reports these Federal standards.

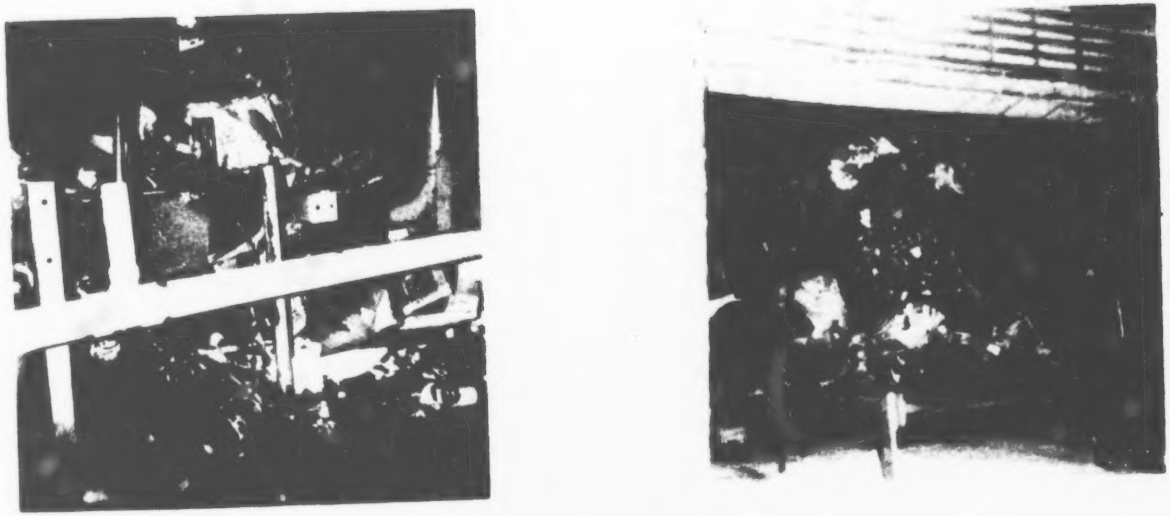


FIGURE 84. Refuse scattered at the discharge valve rooms at Descon Concordia and Camci during periods of prolonged system downtimes.

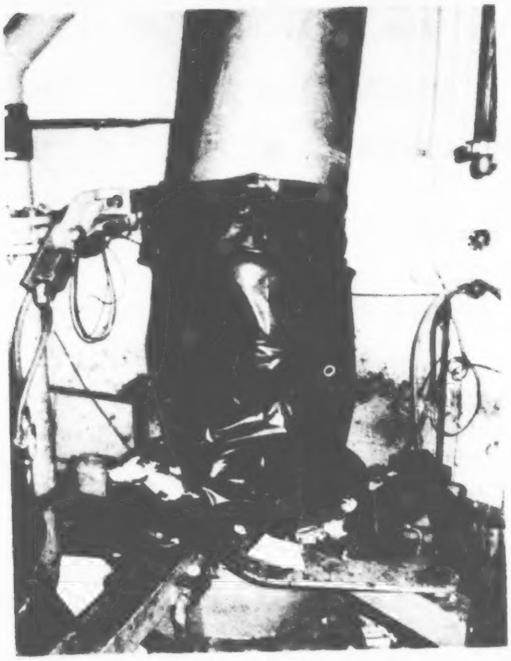


FIGURE 85. Bag placed at base of storage section at Shelley A to collect refuse during prolonged system downtimes.

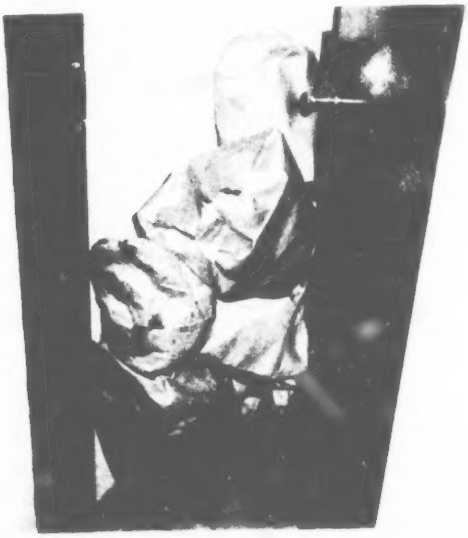


FIGURE 86. A typical chute charging station filled with refuse during a prolonged system malfunction. Note that the door is only partially open because of additional refuse behind the door.

Table 46. NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PARTICULATE MATTER

	Primary Standard		Secondary Standard	
	micrograms/m^3	grains/ft^3	micrograms/m^3	grains/ft^3
Annual geometric mean	75	3.28×10^{-5}	60	2.62×10^{-5}
Maximum 24-hour concentration	260	11.35×10^{-5}	150	6.55×10^{-5}

The results of the total airborne particulate tests on the system air and the system exhaust air are presented in Table 47. The results show that even though the internal air of the PTC system exceeded the Primary Standard during all three test periods, the exhaust air only exceeded the Secondary Standard once. The ambient air exceeded the Primary Standard every time. Thus, it can be deduced that the dust collector was able to filter the system air such that it removed about 85 percent of the total airborne particulate matter. Further, the system exhaust air actually had a lower concentration of total airborne particulate than the ambient air.

Table 47. RESULTS FOR TOTAL AIRBORNE PARTICULATE MATTER SAMPLING TESTS[1]

Date	System Air	System Exhaust Air	Ambient Air
February 24-28, 1975	4.73	1.47	3.92
June 23-27, 1975	6.07	2.74	4.45
January 5-9, 1976	30.42	2.11	3.54
Average	13.74	2.11	3.97

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[1] *Total airborne particulate matter is reported in 10^{-5} grains/cu ft.*

The viable particle concentrations of the system exhaust air and internal air were measured and compared to ambient air. The results for three test periods are presented in Table 48. The results indicate that the dust collector removed about 48 percent of all viable particles. The results also show that the viable particle concentration in the system exhaust air was lower than the concentration in the ambient air.

Table 48. RESULTS FOR VIABLE PARTICLE CONCENTRATION SAMPLING TESTS[1]

Date	System Air	System Exhaust Air	Ambient Air
February 24-28, 1975	4.5	2.3	2.7
June 23-27, 1975	8.3	5.8	10.0
January 5-9, 1976	9.0	3.3	4.6
Average	7.3	3.8	5.8

---

[1] *The viable particle concentration is reported in colonies/cu ft.*

Both the particulate matter and viable particle concentrations from the system exhaust air were lower than the ambient air concentrations, and thus complied with the design specifications.

Noise Levels --

A comparative analysis of the noise levels attributed to the refuse collection activities for the PTC system to the ambient noise levels and to OSHA standards was conducted. There was no indication of excessive noise levels from the PTC system. In many cases, the ambient noise levels in the public rooms adjacent to the discharge valve rooms were greater than the noise attributed to the PTC system operations.

The noise levels in the CEB ranged from 74 to 85 db due to the continuous operation of the total energy plant. The noise levels increased to between 80 to 90 db during operations of the PTC system, however, these levels were transient and lasted less than six minutes per hour. These noise levels were well within the regulations promulgated by OSHA, and presented no problems.

Noise was also produced by the pull-on container truck when the refuse containers were changed. Nevertheless, the noise level was about 95 db and only lasted for about ten minutes. This activity occurred once per week.

When the PTC system was operating properly, the noise levels from the system at the site were less than ambient noise levels. Therefore, tenants were unaware of noise from system operations and the system was found to be acceptable for residential use.

Aesthetics.--

The design of the PTC system considered features to preserve the site aesthetics. The following major system components were either housed in the CEB or below grade:

- Main transport line,
- Collection hopper,
- Dust collector,
- Main exhausters,
- Vent fan,
- Compactor and container handling system, and
- Central control panel.

The discharge valve rooms were placed in the basement areas of each building. The building chutes were designed to be internal to the structure, or blend into the site. Figure 87 shows one charging station on the Descon Concordia deck.

A bulk waste collection service was provided by the site personnel. The residents would leave large boxes, furniture, and other large refuse outside each building. Trash receptacles were provided, but there were too few to collect all the refuse. Thus, a large portion of the refuse was left on the ground detracting from the site aesthetics. Figures 88 and 89 show refuse at the Shelley A and Camci buildings, respectively. This refuse was collected by small carts (Figure 90).

Service Vehicles --

A service vehicle came to the site once each week to exchange refuse containers. An empty container was delivered and the full container was hauled to a sanitary landfill. The duration of each visit was about twenty minutes and the vehicle, a pull-on container truck, produced less noise than a typical rear-packer vehicle. The site access road for service vehicles was planned to minimize the visual impact or these vehicles on the site. The success of these features was demonstrated in the tenant survey report. The majority of the residents were unaware that a private contractor hauled the site refuse away.

FIGURE 87. One charging station at the deck of Descon Concordia, showing how the design preserves site aesthetics.

FIGURE 88. Bulk waste left daily outside Shelley A to be picked up by site personnel.

FIGURE 89. Bulk waste left daily outside Camci to be collected by site personnel.

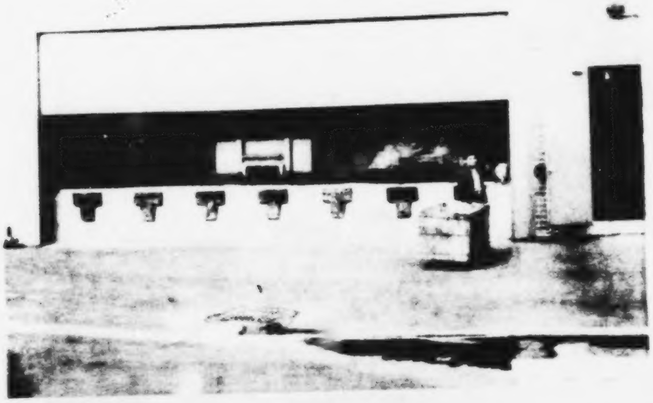

FIGURE 90. A workman with a small chart about 4'x4'x4' in size used for collecting refuse.

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APPENDIX A

TEST PLAN FOR MEASUREMENT OF TOTAL AIRBORNE PARTICULATES GENERATED BY THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

This procedure was used to determine total airborne particulate matter generated by the pneumatic trash collection system at the Operation Breakthrough site in Jersey City, N.J. Tests were performed on three occasions. On each occasion three locations were tested each day for five days. The test consists of air sampling by the high volume method. Three locations were sampled simultaneously: the outside air adjacent to an air intake, the system air taken from the hopper, and the system exhaust air. The total particulate concentrations were determined for each location by dividing the weight gains of the filters by the volume of air sampled. Comparison of the outside air with the hopper sample gave a measure of air quality within the system prior to filtration. Filter efficiency was determined by a comparison of the hopper sample with the exhaust sample. Comparison of the exhaust air with the outside air gave a measure of the overall effect of the system on air quality.

PROCEDURE

1. Fifteen filters are required on each occasion for the test. At least twenty filters should be processed through steps 2 to 7 in order to have a few extra filters in case of difficulty.

2. Visually inspect each filter to be used. Hold the filter up to a light source and look for pinholes, loose particles, or other defects. Discard filters with visible imperfections.

3. Number each filter on two diagonally opposite corners with a felt tip pen or other suitable marker.

4. Allow the filters to come to equilibrium in a standard conditioning environment for 24 hours. This environment should have a relative humidity less than 55% (variation in the 0 to 55% range is not a serious problem). The conditioning environment must be easily reproducible. If a dessicating chamber is used for the conditioning environment, an indicator dessicant such as activated alumina should be selected. This dessicant is checked every day and replaced when necessary as indicated by a color change. Temperature should be maintained within ± 5°F during equilibration.

5. Check the calibration of the analytical balance by weighing a standard weight. Actual and measured values should be within 0.5mg. If they are not, check the balance with other weights. Record actual and measured weights in the lab notebook.

6. Weigh each filter on the analytical balance within 5 minutes of removing it from the conditioning environment. Record filter number and weight.

7. Place each weighed filter in an envelope to protect it from damage. Label the envelope with the filter number. Care must be exercised to prevent folding or creasing the filters before use.

8. If the sampler is located in a shelter,wipe the inside surfaces of the shelter clean of dust and loose particles before installing a clean filter. Install the filter on the sampler at its sampling location. Place the filter on the wire screen rough side up. Center the filter on the screen so there is a 1/2 inch border. Tighten the wingnuts so that the rubber gasket makes an airtight seal against the fact of the filter. Tighten diagonally opposite nuts first to prevent distortion of the frame and give a more even tightening. Avoid tightening excessively since this might cause the filter to stick to the gasket. Record filter number, location, and date.

9. Turn on the sampler and let it warm up for at least 5 minutes. Read the flow rate of air through the sampler with a flow rate meter. The flow rate meter consists of a vacuum gauge connected to the exhaust end of the sampler blower. The gauge calibration is established by comparison with a standard measurement done in the laboratory previous to taking samples at the site. Refer to the separate section entitled Sampler Flow Rate Calibration for details of the procedure. Record initial flow rate and starting time. If the temperature or pressure of the air at the time of sampling differs significantly from the temperature and pressure of air at the time of gauge calibration, flow rate should be adjusted. The following equation should be used.

$$Q_2 = Q_1 \left(\frac{T_2\ P_1}{T_1\ P_2}\right)^{1/2}$$

where: Q_1 is the flow rate read from the gauge

Q_2 is the adjusted flow rate

T_1 is the temperature at the time of gauge calibration expressed in °R

T_2 is the temperature at the time of sampling expressed in °R

P_1 is the pressure at the time of gauge calibration expressed in inches of mercury

P_2 is the pressure at the time of sampling expressed in inches of mercury.

10. Collect the sample. Sampling will be performed on three occasions. On each occasion samples will be collected from three locations: the outside air adjacent to an air inlet, system air from the hopper, and exhaust air from the system. A sample will be collected from each location each day for five consecutive days.

11. Samplers at the exhaust and air inlet valve can be allowed to run continuously during the day. The sampler at the hopper cannot be allowed to run continuously because operation of the PTC system creates a pressure drop that could reduce or entirely cancel the flow of air through the sampler. The hopper sampler will be operated for 15 minutes beginning approximately 2 minutes after each cycle of the PTC system. Record time and duration of operation for this sampler each time it is turned on.

12. Read and record the flow rate at the end of the sample collection period. The final flow rate should not be less than 20 ft^3/min or the motor will heat up and a valid sample is not obtained. Record the stop time.

13. Remove the exposed filter from the supporting screen of the sampler by grasping it gently at the ends (not the corners) and lifting it upward. Inspect for leakage which might bias results. Check for pieces of filter sticking to the gasket.

14. Fold the filter lengthwise with the exposed side in. Use a large paper clip at each end to keep the filter from unfolding. Return the filter to the properly numbered envelope for storage until conditioning and weighing in the laboratory.

15. It should be noted if there were any power outages or other unusual conditions during the sampling period which might affect the results.

16. Allow the exposed filter to come to equilibrium for 24 hours in the same conditioning environ-

ment used for the clean filters in step 4. Time spent in the conditioning environment should be constant within a few hours for all filters since some samples show a continued weight loss for several days.

17. Repeat step 5.

18. Repeat step 6 using the exposed filters.

19. Calculate the weight of the sample on each exposed filter using the clean weight from step 6 and the exposed weight from step 18.

20. Calculate the average flow rate for each sample by averaging the initial flow rate from step 9 and the final flow rate from step 12.

21. Calculate the time interval over which the sample was taken. For the hopper samples it will be necessary to compute the length of each of the short intervals and then add the intervals to get total sampling time.

22. Take the product of average flow rate from step 20 with the sample interval from step 21 to get total volume of air sampled.

23. Compute the equivalent of the sampled volume at standard temperature and pressure using the formula:

$$V_2 = \frac{T_2}{T_1} \frac{P_1}{P_2} V_1$$

where: V_1 is the sampled volume computed in step 22

V_2 is the equivalent of the sampled volume at standard temperature and pressure

T_1 is the temperature of the sampled air as given by weather data for the site (expressed in °R)

T_2 is the standard temperature 70°F which must be expressed at 530°R

P_1 is the pressure of the sampled air as given by weather data for the site (in inches of mercury)

P_2 is the standard pressure 29.92 inches of mercury

T_2 and P_2 could be chosen to be any convenient values but the same values must be used for all samples.

24. Express the weight from step 19 in grains and the volume V_2 from step 23 in cubic feet. Take the quotient to find particulate concentration in grains per cubic foot for each sample.

25. Average the particulate concentrations for each location over the five day period.

Sampler Flow Rate Calibration

Prior to using the high volume air sampler it is necessary to calibrate the flow rate meter used with it. The flow rate meter could be either a vacuum gauge or a manometer. Flow rate is measured by connecting the meter to the pressure tap at the outlet end of the blower motor. Pressure read on the meter indicates flow rate.

To translate the pressure reading on the flow meter into a flow rate a meter calibration curve must be established in the laboratory. A Sierra Instruments Model 330 flow calibrator is used. The procedure is as follows:

1. Mount the Model 330 at the intake end of the sampler. Connect a manometer to its pressure tap.

2. Connect the vacuum gauge or manometer to be used as a flow rate meter to the pressure tap at the exhaust end of the blower motor housing.

3. Connect the sampler's electrical plug to an autotransformer or other variable voltage source. Varying the voltage changes the speed of the motor and, therefore, the flow rate.

4. Set the voltage to the normal operational voltage of 115 volts. Pressure reading of the manometer connected to the Model 330 calibrator should be 10 to 12 inches of water. Allow the sampler to warm up for about five minutes. Check the pressure every minute to make sure

that the flow rate has stabilized. When it has, proceed with calibration.

5. To construct the calibration curve, vary voltage to the sampler motor. Begin by settling voltage to obtain a pressure of one inch in the manometer connected to the Model 330 calibrator. Allow the sampler to run for about 15 seconds, making sure that the pressure reading does not change significantly. Record the pressure reading on the flow meter. Continue by setting the voltage to produce pressure readings on the calibrator manometer at one inch intervals from two to twenty inches. Record the flow meter reading at each pressure. Pressures of one to twenty inches include flow rates from 20 to 75 cfm, the range normally encountered in high volume samplers.

6. Repeat step 5 two times. Average flow meter readings for each pressure from the three trials. Record the average.

7. Record the atmospheric temperature and pressure during the three calibration runs.

8. Use the average flow meter readings and the manufacturer's calibration curve for the Model 330 calibrator to construct a calibration curve for the flow rate meter. The curve should show flow rate in cfm versus the pressure reading on the flow rate meter.

APPENDIX B

TEST PLAN FOR MEASUREMENT OF TOTAL AIRBORNE VIABLE PARTICLES GENERATED BY THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The following procedure was used to measure total airborne viable particles generated by the pneumatic trash collection system at the Operation Breakthrough site in Jersey City, New Jersey. These tests were conducted on three occasions. For each test period three locations were tested daily for five days. The locations were at a remote outdoor location for ambient air conditions, inside the collection hopper for internal system air conditions and at the exhaust vent for system exhaust air.

The concentrations of the airborne particulates were sampled by an Andersen 2000 sampler. The total airborne viable particle concentrations were determined for each location by dividing the number of colonies by the volume of air sampled. Comparison of the ambient air to the system internal air was a measure of air quality attributed to the system before filtration. The filter efficiency was determined by a comparison of the system internal air with the system external exhaust air. Comparison of the system exhaust air to the ambient air was a measure of the overall effect of the system on air quality.

PROCEDURE

1. One hundred-forty sterilized Petri dishes filled with Standard Methods agar (plate count agar) should be prepared for each test period. Eighteen dishes are required daily and there should be at least ten more prepaired each day in case of accidents and contamination.

2. The Petri dishes and aluminum covers must be sterilized before the dishes can be filled with the plate count agar. Petri dishes can be placed in an autoclave for decontamination; however, the aluminum covers must be decontaminated in a disinfectant and rinsed well. Both Petri dishes and aluminum covers are: (1) washed in warm water with a suitable cleaning agent, (2) rinsed with tap water, and (3) rinsed with distilled water. The Petri dishes and aluminum covers are sterilized in a hot air sterilizer at 160°C for two hours.

3. Twenty-seven ml of melted, sterile plate count agar is poured into each sterile Petri dish with an automatic pipette or a 30 ml syringe with a number 15 or larger needle. An aluminum cover is placed over each Petri dish. The Petri dishes with the plate count agar are inverted and refrigerated until the test day. The Petri dishes must be at room temperature before they can be used.

4. The Andersen 2000 viable particle sampler should be checked for the proper flow rate of one cubic foot per minute before each test period. This can be performed by either a dry gas meter or a wet test meter.

5. The six Petri dishes were placed in the six-stage Andersen sampler. Each dish was visually inspected for plate count agar, decontamination and water droplets. The Petri dishes with the water droplets and decontaninated areas were not used. The Petri dishes were placed in each stage of the sampler, beginning with the lowest (#6) stage. The

aluminum cover was removed and the proper section for the sampler was placed over the Petri dish. The entire sampler was loaded in this manner. A plastic cover was placed over the inlet for the sampler, until the test run was started.

Note: Before the first test period ambient air, system internal air and system external air were sampled for 5, 10, 15, 20, and 30 minute intervals to determine suitable sampling time periods. It was noticed that a short time period would produce very low colony counts, and that the viable particle concentrations were inaccurrate. Furthermore, a long time period would produce partially and fully obscured Petri dishes and invalid colony counts. For valid results for the viable particle sampling test, the following sampling time intervals were made based on the results of this initial sampling:

Location	Time interval
Remote outdoor for ambient air	20 to 30 minutes
Inside collection hopper for system internal air	10 to 15 minutes
Exhaust vent for system external air	20 to 30 minutes

6. The ambient air, system internal air,and system external air were sampled once each day. The Andersen sampler was loaded as previously discussed in step 5, and placed at one test location. The plastic cover to the inlet of the sampler was removed, and the pump was started. The pump was stopped after the proper time, as mentioned in step 5, and the plastic cover was placed on the inlet of the sampler. The test location, and starting and stopping times were recorded.

7. The Andersen sampler was unloaded and an aluminum cover was placed over each Petri dish. The Petri dishes were inverted.

8. A piece of masking tape was placed on each inverted Petri dish and was marked with the sample run number and stage number. These numbers were also recorded with the other data.

9. The Petri dishes were incubated at 35°C for 48 hours.

10. The number of colonies on each dish were counted using a Quebec colony counter. The Quebec colony counter consists of a source of illumination, a grid used to keep track of colonies that have been counted, and an optical instrument to magnify the colonies being counted. The total number of colonies was so low in these tests that every colony on each Petri dish was counted.

11. The concentration of viable particles were computed after the colony counts were made. The concentration was the quotient of the colony counts divided by the volume of air. The volume of air was the product of the elapse time in minutes times the flow rate which was one cubic foot per minute.

APPENDIX C

TEST PLAN FOR CHARACTERIZATION OF THE SOLID WASTE CONVEYED BY THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

This procedure was used to characterize solid waste transported by the pneumatic trash collection system at the Operation Breakthrough site in Jersey City, New Jersey. Tests were performed on three occasions. For every occasion, one 300-pound sample of refuse was removed from the compactor for characterizing the solid waste. A 5 to 10 pound sample was placed in a sealed trash bag for determining the moisture content. Moisture content was determined by weight differences before and after a drying cycle. Density was determined by measuring sample weight and volume. Composition of the solid waste passing through the system was determined by manually separating the samples into the following 10 categories:

(1) Paper
(2) Fines (Refuse which passed through a one-inch sieve)
(3) Food
(4) Glass
(5) Metal
(6) Plastic
(7) Textiles
(8) Wood
(9) Rocks
(10) Yard Waste

PROCEDURE

1. Sample collection should begin on the first cycle of the day at 7:00 a.m. Since approximately 50 pounds of refuse is collected per cycle, six or seven cycles will be needed to obtain a sample of the required 300-pound size. This estimate of the number of cycles required is based on current operation of the system at the rate of 30 cycles per day.

2. In order to obtain data on variation of the load to the system, the six or seven cycles used for collecting the sample will be spaced at intervals of two to three hours. The cycles used will be those at 7:00 a.m., 10:00 a.m., 12:30 p.m., 3:00 p.m., 5:30 p.m., 8:00 p.m., and 10:00 p.m.

3. It will be necessary to have an empty container mounted on the compacter before each cycle and removed from the compactor after each cycle at the indicated times. Movement of containers will be done by site management personnel.

4. After each cycle remove the accumulated refuse from the compacter container. The refuse will be temporarily stored in plastic bags of the three or six bushel size. If the three bushel size is used, approximately 135 bags will be required for collecting the composite samples, depositing sorted material, storage, and final disposal.

5. Transport the sample to the sorting location. Sorting could be done in the room on the second floor of the central equipment building where the hopper, filter, and exhausters are located.

6. Weigh and measure the volume of the composite sample after each cycle. Measure the volume by using a container of known size such as a bushel basket. Record the number of times the sample fills the container. Fill the container from the plastic trash bag and then dump the contents of the container onto a large canvas or plastic sheet for sorting.

7. Separate one-eighth of the pile for use in a drying cycle to determine moisture content. Obtain one-eighth of the total by dividing into halves three times. Weigh the separated portion and store in a tightly sealed 18 quart plastic bag. Label the bag with the date and time of the cycle from which the sample was obtained.

8. Separate the remaining seven-eights of the sample into the 10 categories described in the evaluation plan: paper; metal; glass and ceramics; textiles; plastic, rubber, and leather; food waste; garden waste; wood; rocks; and fines (material which passes a one-inch sieve). There will be a three bushel trash bag for each category. As soon as sorting is completed, seal the bags to prevent evaportation of moisture. If sorting is interrupted, seal the bags containing both the composite and the sorted sample until sorting can be resumed.

9. Weigh the bags and record the weights after sorting has been completed. When a bag is filled, replace it with an empty one and continue sorting after recording which bag was replaced.

10. At the end of a day of sampling dispose of the sorted refuse.

11. Return the samples to be used for determining moisture content to the laboratory. Weigh the container(s) to be used for holding the samples during drying to the nearest gram. Fill the container(s) with sample material and reweigh. Record data and time of cycle from which sample was taken with the weights of the empty and full containers. Dry samples for a minimum of 24 hours at 75°C in a drying oven. Weigh samples and record weight. Compute percentage moisture content as the difference between wet and dry weights. Average the percentage moisture for all the samples from one day. Record the computed moisture content for comparison with other samples.

APPENDIX D

TEST PLAN FOR CHARACTERIZATION OF THE WEEKLY LOAD PROFILE FOR THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

This procedure was used to characterize the weekly load profile of solid waste transported by the pneumatic trash collection system at the Operation Breakthrough site in Jersey City, New Jersey. The test period was conducted over a one week period from September 26 to October 3, 1975. The test recorded the weight of refuse conveyed by the PTC system for every cycle. Observation of the daily loads presented any trends in the weekly profile to assist in eliminating nonessential collection cycles to enhance system performance.

PROCEDURE

1. The refuse container must be removed from the compactor, and a plywood pen must be constructed in place of the container. The pen would detain the refuse for each cycle until the refuse could be weighed.

2. There should be a supply of plastic bags and a 30-gallon trash can to place the refuse into for weighing on a scale. The refuse for each cycle would be placed into bags and weighed. The weights for each cycle are recorded.

3. The scale has an adjustable pointer so that the empty trash can may be placed on the scale, and the adjusted pointer could be zeroed. Thus, the weight for the refuse is read directly from the scale by the adjustable pointer.

4. The adjustable pointer should be checked periodically to ascertain that it is zeroed when an empty trash can is weighed.

5. The refuse samples are disposed into the refuse container after weighing.

6. At the end of each test period, the plywood pen is dismantled and the refuse container is reconnected to the compactor.

APPENDIX E

TEST PLAN FOR DETERMINATION OF THE LOAD CAPACITY FOR THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The following procedure was performed to determine the transport velocities of refuse samples for the load capacity test. The test was conducted on June 9 and 10, 1975 and on December 2, 1975. The density and the transport velocities of refuse samples resembling typical residential and bulky solid waste were measured. The transport velocities of refuse samples for typical residential solid waste were compared to design estimates. The transport velocities of bulk waste were measured so that a comparison could be made with the design specifications. These specifications state that the PTC system must collect refuse with densities ranging to 50 pounds per cubic foot.

PROCEDURE

1. Test loads were put into the system via the chute at discharge valve DV-3. Discharge valve DV-3 is located in the small shed south of the Shelley A building. The location was selected since it was the only location where tenants could easily be prevented from throwing refuse in on top of the test loads during the procedure.

2. Before the tests, steady state air velocities at the filter and at air inlet VB-B (located at Shelley A South adjacent to DV-3) were measured. Air inlet valve VB-B was opened and exhauster #2 was turned on manually from the central control panel. This configuration was used for all load tests. The air velocity at both the filter and VB-B was 50 mph.

3. The velocity at which a test load was transported through the system was measured by observing as it entered the transport pipe at DV 3 and emerged from the transport pipe upon entering the cyclone at the same time. One stopwatch was held by the observer at DV-3. The other stopwatch was held by the observer at the hopper. A test load was put into the chute. Discharge valve DV-3 was opened manually be the control panel next to it. When the test load entered the system, the observer at DV-3 stopped his stopwatch. When the observer at the hopper saw the test load come into the hopper, he stopped his stopwatch. Elapsed time for transport the system was the difference of the times indicated by the two stopwatches. After each test load, the observers resynchronized their stopwatches to zero by a countdown procedure over walkie talkies. The length of the transport pipe from DV-3 to the hopper was measured from drawing 8881F of system blueprints furnished by Envirogenics and it was 660 feet. Velocity of transport was determined by dividing 660 feet by the elasped time. Some times and velocities are indicated as ranges for those cases which the entire load did not arrive at one time. There was an interval of a few seconds for the loose materials during which the load emptied into the hopper.

APPENDIX F

TEST PLAN FOR DETERMINATION OF THE POWER CONSUMPTION FOR THE MAIN EXHAUSTERS FOR THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The following procedure was conducted to determine the electricity used by a main exhauster during a typical cycle. The test was performed on September 3 and repeated on December 15, 1975. Each test comprised recording the elapsed operating time and instantaneous power of each exhauster for three test runs. The electricity required for an exhauster is the product of the elapsed operating time times the average value of instantaneous power.

PROCEDURE

1. The 2 rpm test motor was installed in recorder 7. A new roll of strip chart paper was placed in this recorder. The green pen, which records the turbblower power signal was put in this recorder. The other two pens were removed.

2. The PTC system was placed in the automatic mode. Whenever the manual start buttom was depressed, a complete automatic cycle was made. During each trial, times were recorded as soon as the green pen showed that an exhauster was running, and at the end, when the green pen dropped to within two percent of the range. The difference between these times is the elapsed time for that trial. The exhauster number was also recorded. There were no malfunctions or skipped steps through out the entire test.

3. The strip chart was removed from the recorder for analysis. The original 1/180 rpm motor was re-installed in the recorder, as well as the regular recorder strip chart and pens.

4. Values were summed whenever the power signal crossed a vertical line. The average scale reading, its standard deviation, and number of data points were reported. This process was repeated for each new trial.

5. The raw data were used for calculating the elapsed time, average power, and energy consumed. The average power was calculated by multiplying the average scale reading by 1.60. This is a conversion factor for this signal and its units are kilowatts (kw). The average power is also reported in units of horsepower (hp). The conversion factor, kw = 1.34102 horsepower was used. The energy used is reported in units of kilowatt hours (kwh), and is found by:

   $$\text{Power (kw)} \times \text{Elapsed Time (min)} \times \frac{1\text{ hr}}{60\text{ min}} = \text{kwh}$$

6. Average values for elapsed time, power, and energy consumed for each exhauster were reported.

APPENDIX G

TEST PLAN FOR DETERMINATION OF AN OPTIMUM SCHEDULE FOR THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The optimal scheduling test determined the fewest number of automatic daily cycles which provide for a reasonably high level of collection service. During the load capacity test, it was noticed that the load for many cycles were lower than fifty pounds. The optimal scheduling test observed the performance of the PTC system with a reduced number of daily cycles that eliminated many superfluous cycles.

PROCEDURE

1. The PTC system was studied to identify those components which placed a limiting factor on the size for a cycle load. These components were the collection hopper, the compactor, and the storage sections for the vertical trash chutes.

2. Each identified component was examined to determine the load that it could adequately handle, and the minimum load was determined to be the ultimate cycle load.

   a) Collection hopper--The hopper has a limited volume for refuse, but it was apparent that this volume exceeded the volume of refuse which could be safely handled by the compactor. Therefore, the analysis for the collection hopper was not continued.

   b) Compactor--The compactor, which operated on a three-stroke cycle, has a chamber with a volume of 36.75 cubic feet. The capacity of the compactor was computed to be three times the chamber volume or about 110 cubic feet.

   c) Vertical trash chutes--The analysis of the vertical trash chutes considered the maximum volume of refuse for a single trash chute, and the maximum volume of refuse for all the trash chutes, since the loads for each trash chute were not equivalent. Each trash chute has a limited capacity. Once this capacity is surpassed, a chute blockage will probably occur. Blockages generally do not occur unless the accumulation is higher than the first floor. The estimated volume of the chute to the first floor is one cubic yard. Thus, one cubic yard could be allowed to accumulate in a chute before it would be necessary to cycle the system. The chute in which refuse would accumulate most rapidly would be the chute in the building with the greatest number of dwelling units occupied. Site occupancy figures were obtained from the site management office. There were 472 units occupied on the site. The building with the greatest occupancy is Shelley A with 150 rented units. Assuming each dwelling unit generated the same amount of refuse, Shelley A dwelling units generated 150/472 = .318 of the total site refuse. If the one cubic yard of refuse were allowed to accumulate before a cycle at Shelley A, which is .318 of the total refuse, then about three cubic yards (81 cubic feet) could be collected on one cycle.

d) System capacity--The capacity of the system was found to be limited to the volume of the storage chutes. The maximum volume of refuse which may be safely collected is about eighty cubic feet.

3. Feasible operating schedules were selected based on the results of the daily load profile test and the maximum volume of refuse (see Section V). The peaks in the daily load profiles were considered as possible cycling times. The daily number of cycles were selected from four to twenty-four cycles.

4. Each operating schedule was tested for several days to observe the performance of the PTC system. All the vertical trash chutes were inspected before each test to insure that there were no chute blockages existing before the test. Any undetected chute blockage would unfavorably biased the test. These chutes were frequently inspected each day during the test to discover any problems.

APPENDIX H

TEST PLAN FOR MEASUREMENT OF THE NOISE LEVELS ATTRIBUTED TO THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The noise levels associated with the collection activities of the PTC system and the ambient noise levels were compared. Furthermore, the noise levels for the PTC system were compared to OSHA regulations. This test determined whether there are excessive noise levels attributed to the PTC system and if these noise levels surpass industrial standards. This test was conducted on March 24 and 25, 1976.

PROCEDURE

1. All noise measurements were made with a General Radio Co. Type 1565-B Permissible Sound Level Meter. This meter was calibrated twice daily by a General Radio Co. Type 1562-A Sound-Level Calibrator.

2. The following discharge valve rooms and adjacent public areas were measured for noise levels during and between system operations:

   a) Shelley A South
   b) Shelley A
   c) Shelley B East
   d) Shelley B West
   e) Descon Concordia
   f) Camci
   g) Descon Decks
   h) Commercial

3. The following system components in the CEB were measured for noise levels between and during system operations:

   a) Vent fan
   b) Main exhauster
   c) Compactor
   d) Collection hopper

   The meter was placed in general proximity and within twelve to six inches of each component during system operations to determine if the noise levels increased.

4. The pull-on container truck was also measured for noise levels during its operation.

5. For each test during system operations, the location, noise level and duration were recorded.

APPENDIX I

TEST PLAN FOR DETERMINATION OF THE SERVICE LIFE FOR THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The following procedure was performed to measure the amount of wear that was experienced by the PTC system components during the 18-month monitoring period. These data were used for the analysis of service life for the PTC system. This test was conducted before and after the monitoring period. The following components were closely examined for wear data:

- Main transport line,
- Compactor,
- Discharge valves, and
- Collection hopper.

PROCEDURE

A separate procedure is presented for each component.

MAIN TRANSPORT LINE

1. The test sections were initially characterized by documented and certified reports stating identification, heat, chemical analysis, and hardness.

2. The flanges of the test sections were marked at each end either "front" or "rear" for the upstream and downstream ends at the pipe seam weld. Angular positions along the circumference were indexed from this weld (0°) in a clockwise direction when facing the upstream end. Each flange was marked by stamping the metal.

3. Thickness measurements were taken on the pipe sections using a Branson Caliper capable of ± 0.005 inch accuracy in the following steps:

   a) Mark out a surface grid on each pipe having six inch longitudinal and 15° radial spacings. Identify the longitudinal spacing alphabetically from front to back and the radial spacings numerically clockwise from 0° (the seam weld). In this manner, all points will be referenced from the junction of the seam weld and the front flange (point A-1).

   b) Prepare a data record sheet using the grid format for each pipe.

   c) Calibrate the thickness measurement instrument against standard test sections in accordance with the manufacturers recommendations.

   d) Measure and record the pipe thickness at every grid point. These points were cleaned with a wire brush, rinsed with water and detergent, and prepared for measuring by placing a small amount of hair cream on the point. The hair cream provided a good medium between the test section and the probe for the Branson Caliper so that accurate readings could be made.

4. Sixteen surface impressions were made of interior surfaces at each end of both test sections at 90 degree rotations. Each impression was two inches from the flange and was made by either epoxy or auto body repair compound. The surface was cleaned with a brush, rinsed with water and detergent and prepared by spraying the area with a light layer of furniture polish. The polish allowed the surface replica to be easily removed.

5. The test sections were weighed on a scale.

6. Steps 3 to 5 were performed during the initial and final characterization periods. The places for these readings were carefully located and recorded so that both test periods were examining identical areas.

COMPACTOR

1. The compactor was investigated during the final characterization period. The unit was visually inspected for wear and unusual conditions were photographed.

2. Surface impressions were made of the compactor ram face, top and other areas. The procedure was previously presented.

3. The top of the compactor ram was measured for thickness by the Branson Caliper. The array of points was a straight line four inches from the front of the compactor ram and parallel to it. The first reading was three inches from the edge. The other readings were spaced at two-inch intervals. Four additional readings were made at the end of the compactor ram top. These four readings determine the original thickness of the ram.

DISCHARGE VALVES

1. The discharge valves were visually inspected for wear during the final characterization period. Unusual conditions were photographed. The teflon wearing surface was investigated for missing, loose or chipped sections. Additionally, surface impressions were made of the teflon surfaces.

2. The discharge valve plates were observed for wear. Surface impressions were made of the following plates located at:

    a) Shelley A,
    b) Shelley B East,
    c) Descon Concordia,
    d) Camci, and
    e) An extra one for initial plate conditions.

    These discharge valve plates were measured for plate thickness across two perpendicular axes. One axis was in the direction of travel. The thickness readings started at three inches from the edge and spaced at two-inch intervals.

COLLECTION HOPPER

1. The inside surface of the collection hopper was visually inspected for wear during the final characterization period. Any unusual conditions were photographed.

2. The thickness of the collection hopper was measured directly downstream of the entry point since refuse initially impinged on this area. An array of readings was established at six-inch intervals horizontally and at four-inch intervals vertically.

OTHER COMPONENTS

1. The container handling system was visually inspected for wear during the final characterization period. The following components were particulary investigated:

    a) Power and free motion rollers,
    b) Drive motor, chains and sprockets for the free motion rollers, and

c) Drive motor, chains and sprockets for the hydraulic lift trolleys.

2. Each chute charging station was inspected during the final characterization period. They were examined for proper operation, missing or broken parts, and other unusual conditions.

APPENDIX J

CALCULATIONS FOR THE REGRESSION LINE FOR THE RELATIONSHIP BETWEEN TRANSPORT VELOCITY AND DENSITY

SCOPE

The following analysis was performed to generate a regression line between transport velocity and density. The results from the load capacity test were used in this analysis. It was assumed that there was a linear relationship between these two factors. The transport velocity for refuse of a density of 50 pounds per cubic foot was computed from this relationship, since the PTC system was designed to collect refuse up to 50 pounds per cubic foot.

ANALYSIS

The basic equation for a regression line for an independent variable (X) and a dependent variable (Y) is:

$$Y = bx + (\overline{Y} - b\,\overline{X})$$

where: $\overline{Y} = \frac{\Sigma Y}{n}$

$$\overline{X} = \frac{\Sigma X}{n}$$

$$b = \frac{\Sigma XY - \frac{\Sigma X\,\Sigma Y}{n}}{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}$$

The data for this analysis were reported from the load capacity test, and are presented below:

Test Load Description	Density lb/ft^3 (X)	Velocity ft/sec (Y)
Balsa Wood	8	52.8
White Pine	23	39.1
Fir	30	42.0
Walnut	39	24.4
Maple	47	28.7
Bundled Newspaper (Dry)	25	42.3 Avg. Velocity
Bundled Newspaper (Wet)	46	31.6 Avg. Velocity
Wet Rags	43	36.9

The following quantities are required to determine the equation for the regression line.

$\Sigma X = 261$ $\Sigma Y = 297.8$ $n = 8$

$\Sigma X^2 = 9813$ $\Sigma XY = 8980.0$

$\overline{X} = 32.63$ $\overline{Y} = 37.23$

The numerical value for the parameter b is:

$$b = \frac{8980.0 - \frac{(261)(297.8)}{8}}{9813 - \left(\frac{(261)^2}{8}\right)} = -0.5669$$

The equation for the transport velocity Y of refuse varying in density (X) is:

$$Y = 0.5669\ X + [37.23 - (-0.5669)(32.63)]$$

$$Y = 55.7 - 0.57\ X$$

where: X is the density of refuse in lbs per cu ft

Y is the transport velocity of refuse in ft per sec

The PTC system is designed and constructed to successfully collect refuse of a density of 50 lbs per cu ft. The estimated transport velocity would be:

$$Y = 55.7 - 0.57\ (50)$$

$$Y = 27.2 \text{ ft/sec}$$

APPENDIX K

CALCULATIONS OF THE SERVICE LIFE FOR THE MAIN TRANSPORT LINE

SCOPE

The service life for the main transport line was estimated by a preliminary life cycle analysis. The wear data for the two test sections of the main transport line were used. It was assumed that the wear rate is a constant. The estimated service life, as computed in this analysis, is compared to the 40-year service life requirement in the design specifications.

ANALYSIS

The main transport line was designed and constructed to perform for forty years. The two test sections were examined for wear to determine the service life for the entire line. The line, which is placed under a partial vacuum, is constantly eroded by the passing of solid waste. To prevent the collapse of the line, a minimum wall thickness must be maintained. This analysis determined the value for the minimum wall thickness for the service life estimate. The basic equation for the service life of the main transport line is:

$$L = \frac{t_o - t_m}{w}$$

where: L is the service life in years

t_o is the original wall thickness in inches

t_m is the minimum wall thickness in inches

w is the annual wear rate in inches per year

The minimum allowable wall thickness is determined by the geometry of the main transport line, and by the maximum vacuum level experienced by the line. The maximum vacuum level is at the end of every automatic mode cycle to seal the discharge valve lids onto the valve bases and is about 75 inches H_2O or 2.70 psi vacuum. The following expressions are also required and are based on the geometry:

D_o = outside diameter and is 20 inches.
L = distance between main transport line stiffeners and is 8 feet.

The minimum wall thickness value is determined by an interative process. A minimum wall thickness value (t_m) is assumed and a parameter [$B = P(D_o/t_m)$] is determined (Ref. 26). After B is found and since D_o and t_m are also known, the calculated value for P is checked with the given value of 2.70 psi. Then, the value of t_m is modified so that the pressure is equal to 2.70 psi. This final value of t_m is the minimum wall thickness value.

APPENDIX L

CALCULATIONS OF THE SERVICE LIFE FOR THE DISCHARGE VALVES

SCOPE

Preliminary life cycle analyses were conducted to determine the service life of the discharge valves for the PTC system. These analyses were based on data for the wear of the discharge valve plates. The wear rate for these plates was assumed to be constant. The service life for the discharge valves were compared to the 40-year service life required in the design specifications.

ANALYSIS

The discharge valves were designed to operate for at least for forty years. The discharge valve plates experienced the greatest amount of wear and are identified as critical components. The plates for the discharge valves at Shelley, Descon Concordia, and Camci were measured for thickness by an ultrasonic device. A final discharge valve, located in the CEB, for the Commercial building was uninstalled, and used for a control case. The readings for all the values are reported in Table 49.

The thickness readings for the control case ranged from 0.638 to 0.630 inch. The mean value of the discharge valve plate is 0.633 inch and is 0.005 inch less than the maximum value.

The following procedure was established to determine the service life of each discharge valve plates. The largest value for for each case is considered to be the maximum thickness of the original value surface. The average value of the original value surface is assumed to be 0.005 inch less. The wear incurred in service for one year is assumed to be two-thirds the difference between the average value and the smallest reading since the PTC system operated for eighteen months. The minimum allowable thickness for the value plate was assumed to be identical to the value for the main transport line, or 0.070 inch. The following equation was used to compute the service life:

$$L = \frac{t_o - t_m}{w}$$

where L is the service life in years.
t_o is the original plate thickness in inches.
t_m is the minimum plate thickness in inches.
w is the annual wear rate in inches per year.

Table 49. THICKNESS READINGS FOR THE DISCHARGE VALVE PLATES[1]

Shelley A		Descon Concordia	Camci	Control Case
0.635	0.628	0.638	0.643	0.632
0.632	0.628	0.632	0.652	0.631
0.632	0.628	0.631	0.641	0.636
0.633	0.625	0.630	0.639	0.632
0.634	0.626	0.627	0.636	0.631
0.635	0.630	0.625	0.637	0.630
0.630	0.628	0.623	0.644	0.633
0.629	0.624	0.639	0.632	0.638
0.626	0.624	0.628	0.641	0.635
0.624	0.625	0.632	0.647	0.631
0.625	0.625	0.626		0.637
0.622	0.626	0.628		0.631
0.623	0.627	0.629		0.634
0.627	0.626	0.629		0.636
	0.629	0.630		0.634
				0.631

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[1] *Readings are in inches.*

The results for this test are presented in Table 50.

Table 50. RESULTS FOR SERVICE LIFE CALCULATIONS FOR THE DISCHARGE VALVE PLATES

	Shelley A	Descon Concordia	Camci
Largest thickness (in.)	0.635	0.639	0.652
Average original thickness (in.)	0.630	0.634	0.647
Smallest thickness (in.)	0.622	0.623	0.632
Annual wear rate (in. per year)	0.0053	0.0073	0.010
Service life (years)	106	77	58

APPENDIX M

CALCULATIONS OF THE ENERGY USAGE FOR THE PNEUMATIC TRASH COLLECTION SYSTEM

SCOPE

The annual electricity consumption for the PTC system was computed. The components which used the most electricity were identified. In every case, except for the main exhausters, manufacturers data and operating time were recorded to determine the power consumption. The main exhausters were independently tested for power usage.

ANALYSIS

The annual energy usage for the PTC system was determined by calculating the total electrical demand for all of the system components. The following components were identified as the largest users of electricity:

- Main exhausters,
- Compactor, and
- Vent fan.

The main exhausters operated 6952 cycles annually, and used an average energy amount of 9.04 kwh per cycle. The energy consumption for each main exhauster was measured in the main exhauster power tests. The electricity used by the exhausters is 62,846 kwh per year and is calculated by:

6,952 cycles/yr x 9.04 kwh/cycle = 62,846 kwh/yr

The compactor, which is operated hydraulically, has a 10 hp induction motor with a service factor of 1.15. The elapsed time for the compaction stage during each automatic cycle is 2.5 minutes per cycle. The annual electricity used by the compactor for 6952 cycles is 2484 kwh per year, and is determined by:

$$10 \text{ hp} \times 1.15 \times \frac{1 \text{ kw}}{1341 \text{ hp}} \times 2.5 \text{ min} \times \frac{1 \text{ hr}}{60 \text{ min}} \times 6952 \text{ cycles/yr}$$

$$= 2484 \text{ kwh}$$

The vent fan, which removed odors from the vertical gravity chutes in the residential buildings, operated between system operations except whenever there were system malfunctions (that were not related to compactor failures). The vent fan has a 2 hp induction motor with a service factor of 1.15. The total annual operating time for the vent fan was the total time in a year minus the total cycling times and the total downtime (which were unrelated to compactor malfunctions). The total operating time for the vent fan was 4215 hours and was computed by:

Total time per year - total annual cycle time - [total downtime - compactor downtime]

= total operating time for the vent fan

$$8760\ \text{hr} - 879\ \text{hr} - [4144\ \text{hr} - 478\ \text{hr}]$$

$$= \quad 4215\ \text{hr/yr}$$

The energy consumed by the vent fan was 7229 kwh per year and was found by:

$$4215\ \text{hr/yr} \times 2\ \text{hp} \times 1.15 \times \frac{1\ \text{kw}}{1.341\ \text{hp}} \doteq 7229\ \text{kwh/yr}$$

Additional components for the PTC system were electrically operated. Some of these components are the programmer, the annunciator panel, the central control panel and additional equipment. It was assumed that the additional energy requirements was one-tenth of the energy usage of the main exhausters, compactor and vent fan.

The total amount of electrical energy usage was 72,559 kwh per year. The energy requirements of the major system components are presented in Table 51.

Table 51. ANNUAL ELECTRICAL ENERGY USAGE FOR THE PTC SYSTEM

System Component	Annual Energy Usage
Main Exhausters	62,846 kwh/yr
Compactor	2,484
Vent Fan	7,229
Other System Components	7,256
	72,559 kwh/yr

APPENDIX N

CALCULATIONS OF THE COST PROJECTIONS FOR THE PNEUMATIC TRASH COLLECTION SYSTEM AND THREE CONVENTIONAL ALTERNATIVE SYSTEMS

SCOPE

The annual costs for the PTC system and the three alternative conventional systems were projected for the following years; 1975, 1980, 1985, 1990, and 1995. The annual collection costs were computed by multiplying labor, material and electrical costs by cost indices which were generated for these from a previous study. These indices are presented in Table 52. The adjusted costs for labor, material and electrical costs were added to the annualized capital costs to determine the projected annual costs. The results for the PTC and three conventional solid waste management systems are presented in Tables 53, 54, 55, and 56 respectively.

Table 52. PROJECTED COST INDICES FOR LABOR, MATERIAL, AND ELECTRICAL COSTS

Costs	1974	1975	1980	1985	1990	1995
Labor	100.00	105.10	139.02	182.49	238.18	309.53
Material	100.00	102.55	116.29	131.87	149.54	169.58
Electrical[1]	100.00	105.82	140.29	187.75	251.26	336.25

[1] The cost indices for electricity are based on the costs for No. 2 Diesel fuel oil, since the electricity is produced at the site from five generators.

Table 53. PROJECTED ANNUAL COSTS FOR THE PTC SYSTEM

Costs	1975	1980	1985	1990	1995
Capital	$89,782	$89,782	$89,782	$89,782	$89,782
Labor	26,972	35,676	46,831	61,124	79,435
Material	793	899	1,020	1,156	1,311
Electrical	2,474	3,280	4,389	5,874	7,861
TOTAL	$120,021	$129,637	$142,022	$157,936	$178,389

Table 54. PROJECTED ANNUAL COSTS FOR CONVENTIONAL REFUSE COLLECTION SYSTEM A

Costs	1975	1980	1985	1990	1995
Capital	$ 5,408	$ 5,408	$ 5,408	$ 5,408	$ 5,408
Labor	26,218	34,679	45,522	59,415	77,215
Material	207	274	367	492	658
TOTAL	$31,833	$40,361	$ 51,297	$ 65,315	$ 83,281

Table 55. PROJECTED ANNUAL COSTS FOR CONVENTIONAL REFUSE SYSTEM COLLECTION B

Costs	1975	1980	1985	1990	1995
Capital	$ 5,408	$ 5,408	$ 5,408	$ 5,408	$ 5,408
Labor	20,616	27,269	35,796	46,720	60,716
Material	207	274	367	492	658
TOTAL	$26,231	$32,951	$ 41,571	$ 52,620	$ 66,782

Table 56. PROJECTED ANNUAL COSTS FOR CONVENTIONAL REFUSE COLLECTION SYSTEM C

Costs	1975	1980	1985	1990	1995
Capital	$ 3,354	$ 3,453	$ 3,453	$ 3,453	$ 3,453
Labor	71,206	94,184	123,635	161,367	209,709
Material	40	45	51	58	66
TOTAL	$74,699	$97,682	$127,139	$164,878	$213,228